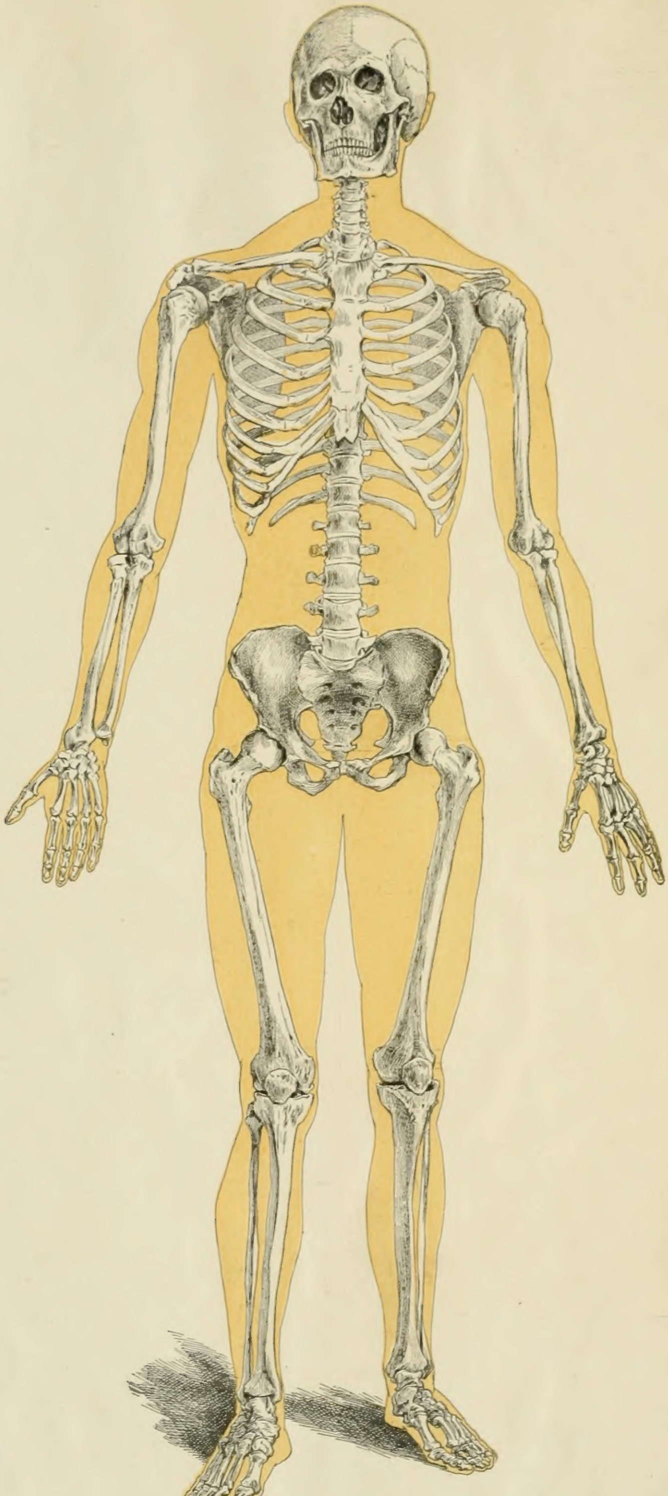
Human Anatomy



The skeleton in relation to the contour of the body.

HUMAN ANATOMY

INCLUDING STRUCTURE AND DEVELOPMENT
AND
PRACTICAL CONSIDERATIONS

BY

THOMAS DWIGHT, M.D., LL.D.
PARKMAN PROFESSOR OF ANATOMY IN HARVARD UNIVERSITY

J. PLAYFAIR McMURRICH, PH.D.
PROFESSOR OF ANATOMY IN THE UNIVERSITY OF MICHIGAN

CARL A. HAMANN, M.D.
PROFESSOR OF ANATOMY IN WESTERN RESERVE UNIVERSITY

GEORGE A. PIERSOL, M.D., SC.D.
PROFESSOR OF ANATOMY IN THE UNIVERSITY OF PENNSYLVANIA

AND

J. WILLIAM WHITE, M.D., PH.D., LL.D.
JOHN RHEA BARTON PROFESSOR OF SURGERY IN THE UNIVERSITY OF PENNSYLVANIA

WITH SEVENTEEN HUNDRED AND THIRTY-FOUR ILLUSTRATIONS,
OF WHICH FIFTEEN HUNDRED AND TWENTY-TWO ARE ORIGINAL
AND LARGELY FROM DISSECTIONS BY

JOHN C. HEISLER, M.D.
PROFESSOR OF ANATOMY IN THE MEDICO-CHIRURGICAL COLLEGE

EDITED BY
GEORGE A. PIERSOL

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in the minds of the student and the physician, will make it easier for the former to learn his anatomy and for the latter to remember and apply it.

Dr. White desires to acknowledge fully his obligations to the existing treatises on applied anatomy and to the various text-books and encyclopedias on surgery and medicine from which many valuable suggestions were gathered. To Drs. Gwilym G. Davis and T. Turner Thomas, his thanks are due for a careful search for possible errors, for friendly criticism, and for help in the selection of illustrations.

The illustrations for the anatomy—a matter of fundamental importance in a work of this character—have received most conscientious attention. The determination to produce a series of original drawings that should faithfully record the dissections and preparations as they actually appear, and not as diagrammatic figures, has involved an expenditure of time and painstaking effort that only those having experience with similar tasks can appreciate. When it is stated that considerably more than two thousand original drawings have been made in the preparation of the figures illustrating the work, some conception will be had of the magnitude of this feature.

In the completion of this labor the editor has been most fortunate in having the assistance of Dr. John C. Heisler, to whose skill and tireless enthusiasm he is indebted for the admirable dissections from which most of the illustrations of the muscles, blood-vessels, nerves, perineum and inguinal region were drawn, as well as for many suggestions for and revision of the drawings themselves. Professor Gwilym G. Davis has also rendered valuable assistance in supplying the dissections for the drawings relating to the Practical Considerations, as well as in supervising that portion of the artist's work.

In addition to the numerous dissections and preparations made especially for the illustrations, advantage has been taken of the rich collections in the museums of the Medical Department of the University of Pennsylvania, of the Harvard Medical School and of the Wistar Institute of Anatomy, which were kindly placed at the editor's service.

Records of the dissections, in many cases life size, were made in water colors chiefly by Mr. Hermann Faber, whose renditions combine faithful drawing with artistic feeling to a degree unusual in such subjects. The records not made by the last-named artist are from the brush of Mr. Ludwig E. Faber. The translations of the colored records into black and white, from which the final blocks have been made, as well as the original drawings of the bones and of the organs, have been made by Mr. Erwin F. Faber. To the conscientious and tireless efforts of this artist are due the technical beauty that distinguish these illustrations. Mr. J. H. Emerton drew the joints, as well as some figures relating to the gastro-pulmonary system, from dissections and sections supplied by Professor Dwight.

The numerous illustrations representing the histological and embryological details throughout the work, and in addition the sections of the brain-stem under low magnification, are by Mr. Louis Schmidt. In all cases sketches with the camera lucida or projection lantern or photographs have been the basis of these drawings, the details being faithfully reproduced by close attention to the original specimens under the microscope.

Notwithstanding the unusually generous allotment of drawings from original dissections and preparations, advantage has also been taken of a number of illustrations which have appeared in special monographs or in foreign journals or works. With very few exceptions such borrowed illustrations have been redrawn and modified to meet the present requirements, due acknowledgment in all cases being given.

The editor gratefully acknowledges the many kindnesses shown by a number of his associates. Dr. William G. Spiller generously placed at his disposal a large collection of microscopical preparations of the central nervous system, from which drawings of selected sections were made. To Dr. George Fetterolf the editor is indebted for valuable assistance in preparing for and seeing through the press the section on the peripheral nervous system. The collaboration of Dr. Edward A. Shumway very materially facilitated the preparation of the description of the eye, which received only the editor's revision. Likewise, Dr. Ralph Butler, by placing in the editor's hands a painstaking review of the more recent literature on the ear and preliminary account of that organ, greatly lightened the labor of writing the text. Further, Dr. Butler supplied the microscopical preparations from which several of the drawings were made. In addition to assuming the preparation of the index—a no insignificant undertaking in a work of this character—Dr. Ewing Taylor gave valuable assistance in the final revision of the first hundred pages of the book. The editor is indebted to Dr. W. H. F. Addison for repeated favors in preparing special microscopical specimens. Dr. T. Turner Thomas kindly assisted in locating cross-references. This opportunity is taken to express full appreciation and thanks to the various authors and publishers, who so kindly have given permission to use illustrations which have appeared elsewhere.

Very earnest consideration of the question of nomenclature led to the conclusion, that the retention, for the most part, of the terms in use by English-speaking anatomists and surgeons would best contribute to the usefulness of the book. While these names, therefore, have been retained as the primary terminology, those adopted by the Basle Congress have been included, the BNA synonyms appearing in the special type reserved for that purpose. The constant aim of the editor has been to use the simplest anatomical terminology and preference has always been given to the anglicized names, rather than to the more formal designations. Although in many cases the modifications suggested by the new terminology have been followed with advantage, consistent use of the Basle nomenclature seems less in accord with the conceded directness of English scientific literature than the enthusiastic advocates of such adoption have demonstrated.

The editor desires to express his appreciation of the generous support given him by the publishers and of the unstinted facilities placed by them at his disposal throughout the preparation of the work.

University of Pennsylvania,
September, 1907.

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HUMAN ANATOMY.

ANATOMY is that subdivision of morphology—the science of form as contrasted with that of function or physiology—which pertains to the form and the structure of organized beings, vegetal or animal. *Phytotomy* and *Zootomy*, the technical names for vegetal and animal anatomy respectively, both imply etymologically the dissociation, or the cutting apart, necessary for the investigation of plants and animals.

The study of organized bodies may be approached, evidently, from several standpoints. When the details of the structure of their various tissues and organs particularly is investigated, such study constitutes *General Anatomy* or *Histology*, frequently also called *Microscopical Anatomy*, from the fact that the magnifying lens is used to assist in these examinations. The advantages of comparing the organization of various animals, representing widely different types as well as those closely related, are so manifest in arriving at a true estimate of the importance and significance of structural details, that *Comparative Anatomy* constitutes a department of biological science of far-reaching interest, not merely for the morphologist, but likewise for the student of human anatomy, since we are indebted to comparative anatomy for an intelligent conception of many details encountered in the human body. *Developmental Anatomy*, or *Embryology*, also has been of great service in advancing our understanding of numerous problems connected with the adult organism by tracing the connection between the complex relations of the completed structures and their primitive condition, as shown by the sequence of the phases of development. These three departments of anatomical study—general, comparative, and developmental anatomy—represent the broader aspects of anatomical study in which the features of the human body are only incidents in the more extended contemplation of organized beings.

The exceptional importance of an accurate knowledge of the body of man has directed to human anatomy, or *anthropotomy*, so much attention from various points of view that certain subdivisions of the subject are conveniently recognized ; thus, the systematic account of the human body is termed *Descriptive Anatomy*, while when the mutual relations and peculiarities of situation of the organs located in particular parts of the body especially claim attention, such study is spoken of as *Topographical* or *Regional Anatomy*. Consideration of the important group of anatomical facts directly applicable to the diagnosis and the treatment of disease constitutes *Applied Anatomy*.

General Plan of Construction.—Vertebrate animals, of which man represents the most conspicuous development of the highest class,—fishes, amphibians, reptiles, birds, and mammals being the recognized subdivisions of the vertebrata,—possess certain characteristics in common which suffice to distinguish the numerous and varied members of the extended group.

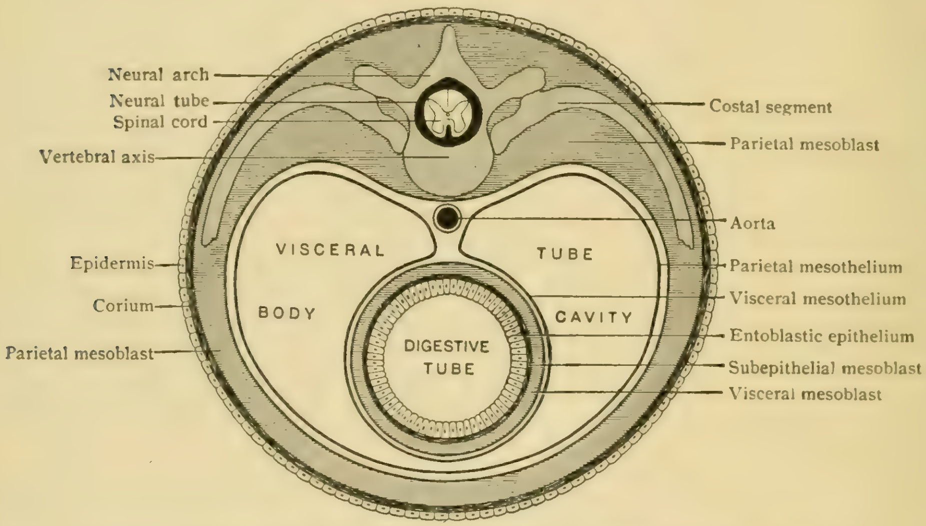
The fundamental anatomical feature of these animals is the possession of an *axial column*, or spine, which extends from the anterior or cephalic to the posterior or caudal pole and establishes an axis around which the various parts of the elongated body are grouped with more or less symmetry. While this body-axis is usually marked by a series of well-defined osseous segments constituting the vertebral column of the higher animals, among certain of the lower fishes, as the sharks or sturgeons, the axial rod is represented by cartilaginous pieces alone ; in fact, the tendency towards the production of a body-axis is so pronounced that the formation

of a primitive axis, the *notochord*, takes place among the early formative processes of the embryo.

In addition to the fundamental longitudinal axis, vertebrate animals exhibit a transverse cleavage into somatic or body-segments. While such segmentation is represented in the maturer conditions by the series of vertebræ and the associated ribs, the tendency to this division of the body is most marked in the early embryo, in which the formation of body-segments, the *somites*, takes place as one of the primary developmental processes. Although these primary segments do not directly correspond to the permanent vertebræ, they are actively concerned in the formation of the latter as well as the segmental masses of the earliest muscular tissue. In man not only the skeleton, but likewise the muscular, vascular, and nervous systems are affected by this segmentation, the effects of which, however are most evident in the structure of the walls of the thoracic portion of the body-cavity.

Disregarding the many variations in the details of arrangement brought about by specialization and adaptation, the body of every vertebrate animal exhibits a fundamental plan of construction in which *bilateral symmetry* is a conspicuous feature. Viewed in a transverse section passing through the trunk, the animal body

FIG. 1.



Diagrammatic plan of vertebrate body in transverse section. (*Modified from Wiedersheim.*)

may be regarded as composed primarily of the axis, formed by the bodies of the vertebræ, and two tubular cavities of very unequal size enclosed by the tissues constituting the body-walls and invested externally by the integument (Fig. 1).

The smaller of these, the neural tube, is situated dorsally, and is formed by the series of the vertebral arches and associated ligaments; it surrounds and protects the great cerebro-spinal axis composed of the spinal cord and the specialized cephalic extremity, the brain. The larger space, the visceral tube corresponding to the body-cavity, or *cœlom*, lies on the ventral side of the axis and contains the thoracic and abdominal viscera, including the more or less convoluted digestive-tube with its accessory glandular organs, the liver and the pancreas, and the appended respiratory tract, together with the genito-urinary organs and the vascular and lymphatic apparatus.

The digestive-tube, which begins anteriorly at the oral orifice and opens posteriorly by the anus, is extended by two ventral evaginations giving rise to the respiratory tract and the liver, a dorsal glandular outgrowth representing the pancreas. The sexual and urinary glands and their ducts primarily occupy the dorsal wall of the body cavity. The vascular system consists essentially of the ventrally placed contracting dilatation, the heart, divided into a venous and an arterial com-

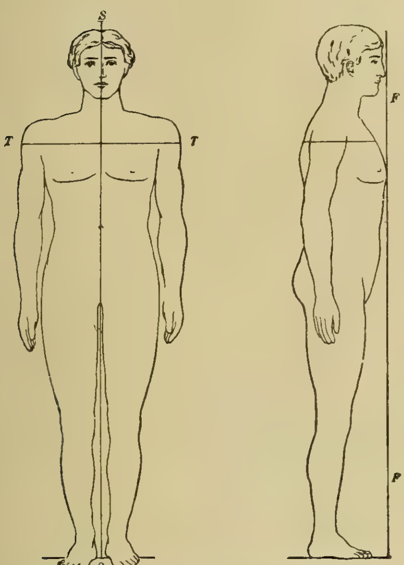
partment, and the great arterial trunk, the aorta, the major part of which occupies the dorsal wall of the space.

The elongated typical vertebrate body terminates anteriorly in the cephalic segment, posteriorly in the caudal appendage ; between these two poles extends the *trunk*, from which project the ventrally directed limbs, when these appendages exist. Just as the axial segments, represented by the bodies of the vertebræ, take part, in conjunction with the neural arches, in the formation of the neural canal, so do these segments also aid in forming the supporting framework of the ventral body-cavity in connection with the series of ribs and the sternum.

Descriptive Terms.—The three chief planes of the vertebrate body are the sagittal, the transverse, and the frontal. The *sagittal plane*, when central, passes through the long axis of the body vertically and bisects the ventral or anterior and the dorsal or posterior surfaces. The *transverse plane* passes through the body at right angles to its long axis and to the sagittal plane. The *frontal plane* passes vertically but parallel to the anterior or ventral surface, being at right angles to both the sagittal and transverse planes (Fig. 2.)

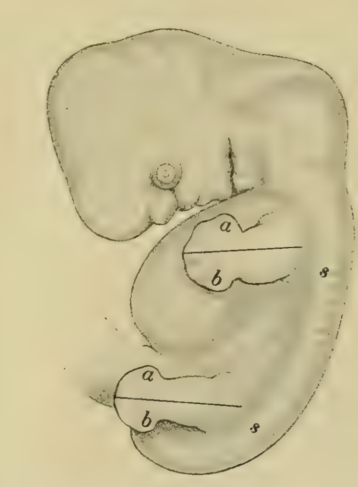
The vertical position of the long axis in the human body is unique, since man,

FIG. 2.



Three principal planes of human body. *T*, *T*, transverse; *S*, *S*, sagittal; *F*, *F*, frontal.

FIG. 3.



Human embryo showing primary relations of limbs. *a*, *a*, preaxial surfaces; *b*, *b*, postaxial; *s*, *s*, somitic segments of trunk.

of all animals, is capable of habitually maintaining the erect posture with full extension of the supporting extremities. The lack of correspondence between the actual position of the chief axis of man and the horizontal fore-and-aft-axis of vertebrates in general results in discrepancies when the three principal planes of the human body are compared with those of other animals. Thus, the sagittal plane alone retains the relation, as being at right angles to the plane of the support, in all vertebrates, although in man its greatest expansion is vertical. The transverse plane in man is parallel with the supporting surface, while it is, obviously, at right angles to the corresponding plane in the four-footed vertebrate ; likewise, the frontal plane in man is vertical, while it is horizontal in other animals.

The various terms employed in describing the actual position of the numerous parts of the human body and their relations to surrounding structures have been adopted with regard to the erect attitude of man and the convenience of the student of human anatomy ; hence, in many cases, they must be recognized as having a limited specific and technical application and often not directly applicable to other

vertebrates. *Superior* and *inferior*, *upper* and *lower*, as indicating relations towards or away from the head-end of the body, are, probably, too convenient and useful as expressing the peculiar relations in man to be readily relinquished, although when directly applied to animals possessing a horizontal body-axis they refer entirely to relations with the plane of support, the additional terms *cephalic* and *caudal* being necessary to indicate relations with the head- and tail-pole. Likewise, "anterior" and "posterior," as referring respectively to the front and back surfaces of the human body, are more logically described as *ventral* and *dorsal*, with the advantage that these terms are directly applicable to all vertebrates. "Outer" and "inner," as expressing relations with the sagittal plane, are now largely replaced by the more desirable terms *lateral* and *mesial* respectively, *external* and *internal* being reserved to indicate relations of depth. *Cephalic* and *caudal*, *central* and *peripheral*, *proximal* and *distal*, are all terms which have found extensive use in human anatomy.

Preaxial and *postaxial*, in addition to their general and obvious significance with reference to axes in common, have acquired a specific meaning with regard to the limbs, the appreciation of which requires consideration of the primary relations observed in the embryo. In the earliest stage the limbs appear as flattened buds which project from the side of the trunk and present a dorsal and ventral surface; subsequently the limbs become folded against the body, the free ends being directed ventrally, while one border looks headward, the other tailward. If an axis corresponding to the transverse plane of the body be drawn through the length of the extremities, each limb will be divided into two regions, one of which lies in front of the axis, and is, therefore, preaxial, the other behind, or postaxial. On reference to Fig. 3 it is obvious that the preaxial border or surface of each limb is primarily directed towards the cephalic or head-end of the animal, and, conversely, that the postaxial faces the caudal or tail-end. These fundamental relations are of great importance in comparing the skeleton of the upper and lower extremities with a view of determining the morphological correspondence of the several component bones, since the primary relations become masked in consequence of the secondary displacements which the limbs undergo during their development.

The terms *homologue* and *analogue* call for a passing notice, since an exact understanding of their significance is important. Structures or parts are homologous when they possess identical morphological values founded on a common origin; thus, the arm of a man, the front leg of a dog, and the wing of a bat are homologues, because each represents the fore-limb of a vertebrate, although they differ in individual function. On the other hand, the wing of a bat and that of a butterfly are analogous, since they are structures of functional similarity, although of wide morphological diversity. Homologue, therefore, implies *structural* identity, analogue implies *functional* similarity. Parts are said to be *homotypes* when they are serial homologues; thus, the humerus and the femur are homotypes, being corresponding structures repeated in the same animal. Where parts possess both morphological and functional identity, as the wing of a bird and of a bat, they are analogous as well as homologous.

THE ELEMENTS OF STRUCTURE.

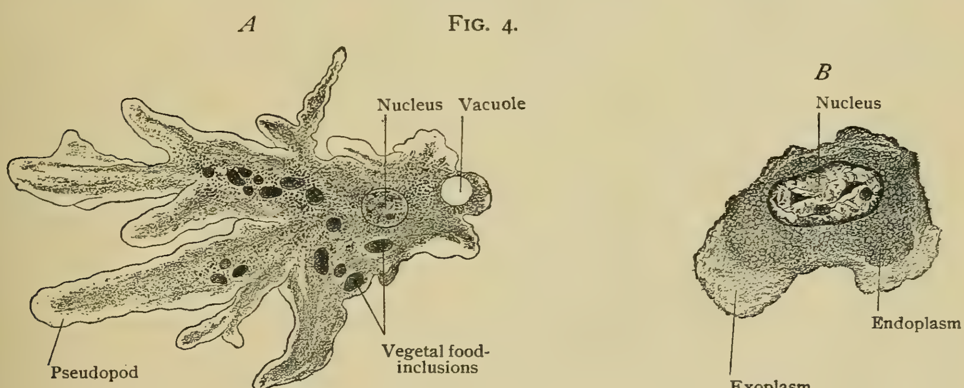
WHEN critically examined, the various organs and parts going to make up the complex economy of the most highly specialized vertebrate—and, indeed, the same is true of all animals whose organization does not approach the extremely simple unicellular type—are found to be constituted by the various combinations of a very small number of *elementary tissues;* these latter may be divided into four fundamental groups :

Epithelial tissues ;
Connective tissues ;
Muscular tissues ;
Nervous tissues.

Of these the nervous tissues are most specialized in their distribution, while the connective tissues are universally present, in one or another form contributing to the composition of every organ and part of the body. The tissues of the circulatory system, including the walls of the blood-vessels and lymph-channels and the corpuscular elements of their contained fluids, the blood and the lymph, represent specializations of the connective tissues of such importance that they are often conceded the dignity of being classed as independent tissues ; consideration of the development of the vascular tissues, however, shows their genetic relations to be so nearly identical with those of the great connective-tissue group that a separation from the latter seems undesirable.

Each of the elementary tissues may be resolved into its component morphological constituents, the *cells* and the *intercellular substances.* The first of these are the

FIG. 4.



A, unicellular animal (*amœba*); *B*, embryonal cell,—leucocyte.

descendants of the embryonal elements derived from the division or segmentation of the parent cell, the ovum, and are highly endowed with vital activity ; the intercellular substances, on the other hand, represent secondary productions, comparatively inert, since they are formed through the more or less direct agency of the cells. The animal cell may exist in either the embryonal, matured, or metamorphosed condition.

The *embryonal cell,* as represented by the early generations of the direct offspring of the ovum, or by the lymphoid cells or colorless blood-corpuscles of the adult, consists of a small, irregularly round or oval mass of finely granular gelatinous substance—the *protoplasm*—in which a smaller and often indistinct spherical body—the *nucleus*—lies embedded. In the embryonal condition, when the cell is without a limiting membrane, and composed almost entirely of active living matter, the outlines are frequently undergoing change, these variations in shape being known as *amœboid movements,* from their similarity to the changes observed in the outline of an active amœba, the representative of the simplest form of animal life, in which

the single cell constitutes the entire organism, and as such is capable of performing the functions essential for the life-cycle of the animal.

As the embryonal cell advances in its life-history, the conditions to which it is subjected induce, with few exceptions, further specializations, since in all but the lowest forms division of labor is associated with a corresponding differentiation and adaptation to specific function.

Vital manifestations of the cell include those complex physico-chemical phenomena which are exhibited during the life of the cellular constituents of the body in the performance of the functions necessary for fulfilment of their appointed life-work. These embrace metabolism, growth, reproduction, and irritability.

Metabolism, the most distinctive characteristic of living matter, is that process by which protoplasm selects from the heterogeneous materials of food those particular substances suitable for its nutrition and converts them into part of its own substance. Metabolism is of two forms,—constructive and destructive. *Constructive metabolism*, or *anabolism*, is the process by which the cell converts the simpler compounds into organic substances of great chemical complexity; *destructive metabolism*, or *katabolism*, on the contrary, is the process by which protoplasm breaks up the complex substances resulting from constructive metabolism into simpler compounds. Vegetal cells possess the power of constructive metabolism in a conspicuous degree, and from the simpler substances, such as water, carbon dioxide, and inorganic salts, prepare food-material for the nutritive and katabolic processes which especially distinguish the animal cell, since the latter is dependent, directly or indirectly, upon the vegetal cell for the materials for its nutrition.

Growth, the natural sequel of the nutritive changes effected by metabolism, may be unrestricted and equal in all directions, resulting in the uniform expansion of the cell, as illustrated in the growth of the ovum in attaining its mature condition. Such unrestricted increase, however, is exceptional, since cells are usually more or less intimately related to other structural elements by which their increase is modified so as to be limited to certain directions; such limitation and influence result in *unequal growth*, a force of great potency in bringing about the differentiation and specialization of cells, and, secondarily, of entire parts and organs of the body. Familiar examples of the result of unequal growth are observed in the columnar elements of epithelium, the fibres of muscular tissue, and the neurones of the nervous system.

Reproduction may be regarded as the culminating vital manifestation in the vegetative life-cycle of the cell, since by this process the parent element surrenders its individuality and continues its life in the existence of its offspring. While the details of the process by which new cells arise from pre-existing cells are reserved for consideration in connection with the more extended discussion of the cell to follow (see page 9), it may here be stated that reproduction occurs by two methods,—the indirect or *mitotic* and the direct or *amitotic*. The first of these, involving the complicated cycle of nuclear changes collectively known as mitosis or karyokinesis, is the usual method; the second and simpler process of direct division, or amitosis, is now recognized as exceptional and frequently associated with conditions of impaired vital vigor.

Irritability is that property of living matter by virtue of which the cell exhibits changes in its form and intimate constitution in response to external impressions. These latter may originate in mechanical, thermal, electrical, or chemical stimuli to which the protoplasm of even the lowest organisms responds, or they may be produced in consequence of the obscure and subtle changes occurring within the protoplasm of neighboring elements, as illustrated by the reaction of the neurones in response to the stimuli transmitted from other nervous elements.

THE ANIMAL CELL.

Ever since the establishment of the Cell Doctrine, in 1838, by the announcement of the results of the epoch-making investigations of Schleiden and Schwann on "The Accordance of Structure and Growth of Animals and Plants," the critical examination of the cell has been a subject of continuous study. Notwithstanding the tireless enthu-

siasm with which these researches have been pursued by the most competent investigators and the great advance in our accurate knowledge concerning the intricate problems relating to the morphology and the physiology of the cell, much pertaining to the details of the structure and the life of the cell still remains uncertain, and must be left to the future achievements in cytology. The account here given of the morphology of the cell presents only those fundamental facts which at the present time may be accepted as established upon the evidence adduced by the most trustworthy observers. The more speculative and still unsettled and disputed problems of cytology, interesting as such theoretical considerations may be, lie beyond the purpose of these pages ; for such discussions the student is referred to the special works and monographs devoted to these subjects. An appreciation, however, of the salient facts of cytology as established by the histologists of the present generation is essential not only for an intelligent conception of the structure of the morphological elements, but likewise for the comprehension of the highly suggestive modern theories concerning inheritance, since, as will appear in a later section, the present views regarding these highly interesting problems are based upon definite anatomical details.

FIG. 5.

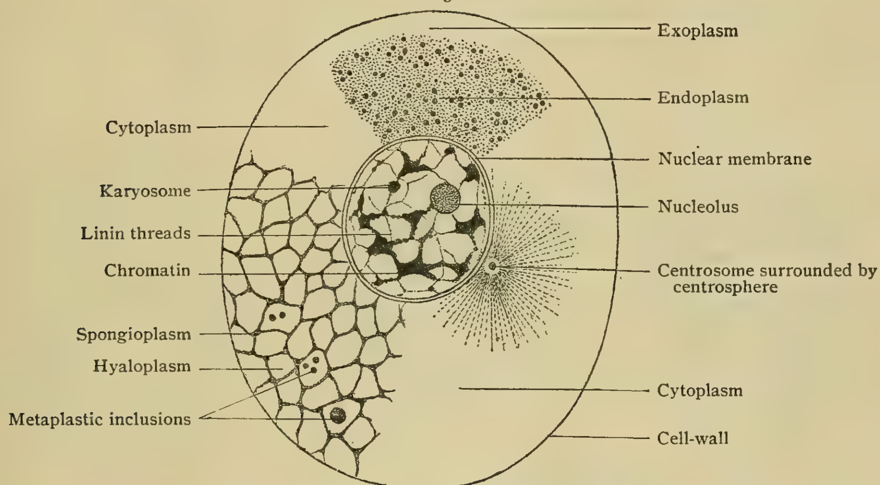


Diagram of cell-structure. In the upper part of the figure the granular condition of the cytoplasm is represented; in the lower and left, the reticular condition.

Notwithstanding the great variations in the details of form and structure, cells possess a common type of organization in which the presence of the cell-body or *cytoplasm* and the *nucleus* is essential in fulfilling the modern conception of a cell. The latter may be defined, therefore, as *a nucleated mass of protoplasm.*

The term *protoplasm*, as now generally employed by histologists, signifies the organized substance composing the entire cell, and with this application includes both the cytoplasm and the nucleus.

Structure of the Cytoplasm.—The cytoplasm, or the substance of the cell-body, by no means invariably presents the same appearance, since it may be regarded as established that the constituents of this portion of the cell are subject to changes in their condition and arrangement which produce corresponding morphological variations ; thus, the cytoplasm may be devoid of definite structure and appear *homogeneous ;* at other times it may be composed of aggregations of minute spherical masses and then be described as *granular*, or, where the minute spheres are larger and consist of fluid substances embedded within the surrounding denser material of the cell, as *alveolar ;* or, again, and most frequently, the cytoplasm contains a mesh-work of fibrils, more or less conspicuous, which arrangement gives rise to the *reticular* condition. The recognition of the fact established by recent advances in cytology, that the structure of cytoplasm is not to be regarded as immutable, but, on the contrary, as capable of undergoing changes which render it probable that a cell may appear

during one stage of its existence as granular and at a later period as reticular, has done much to bring into accord the conflicting and seemingly irreconcilable views regarding the structure of the cell championed by competent authorities.

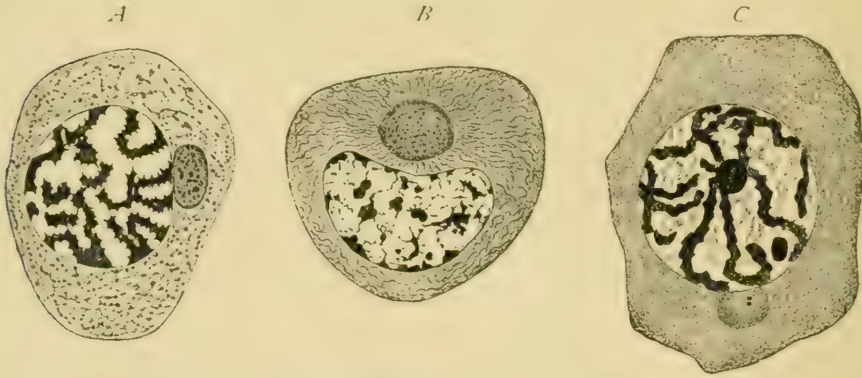
Whatever be the particular phase of structural arrangement exhibited by the cell, histologists are agreed that the cytoplasm consists of two substances,—an *active* and a *passive ;* while both must be regarded as living, the vital manifestations of contractility are produced by the former.

Since a more or less pronounced reticular arrangement of the active and passive constituents of cytoplasm is of wide occurrence in mature cells, this condition may serve as the basis for the description of the morphology of the typical cell.

Critical examination of many cells, especially the more highly differentiated forms of glandular epithelium, shows the cytoplasm to contain a mesh-work composed of delicate fibrils and septa of the more active substance, the *spongioplasm ;* although conspicuous after appropriate staining, the spongioplastic net-work may be seen in the unstained and living cell, thereby proving that such structural details are not artefacts due to the action of reagents upon the albuminous substances composing the protoplasm.

The interstices of the mesh-work are filled with a clear homogeneous semifluid material to which the name of *hyaloplasm* has been applied. Embedded within the hyaloplasm, a variable amount of foreign substances is frequently present ; these

FIG. 6.



Spermatogenic cells, showing variations in the condition and the arrangement of the constituents of the cytoplasm and the nucleus; the centrosomes are seen within the cytoplasm close to the nucleus. *A*, from the guinea-pig × 1685 (*Meves*); *B*, from the salamander × 500 (*Meves*); *C*, from the cat × 750 (*von Lenhossek*).

include particles of oil, pigment, secretory products, and other extraneous materials, which, while possibly of importance in fulfilling the purposes of the cell, are not among its essential morphological constituents. These substances, which are inert and take no part in the vital activity of the cell, are termed collectively *metaplasm*.

Cytoplasm consists, therefore, morphologically, of the spongioplasm and the hyaloplasm ; chemically, cytoplasm consists of certain organic compounds, salts and water. The organic compounds are grouped under the term *proteins*, which are complex combinations of carbon, hydrogen, nitrogen, and oxygen, with often a small percentage of sulphur. The proteins of the cytoplasm contain little or no phosphorus.

Structure of the Nucleus.—The nucleus, during the vegetative condition of the cell, or the "resting stage," as often less accurately called, appears as a more or less spherical body whose outline is sharply defined from the surrounding cytoplasm by a definite envelope, the *nuclear membrane*. Since the nucleus is the nutritive, as well as reproductive, organ of the cell, the fact that this part of the cell is relatively large in young and actively growing elements is readily explained.

The nucleus consists of two parts, an irregular reticulum of *nuclear fibres* and an intervening semifluid *nuclear matrix*, therein resembling the cytoplasm. Examined under high magnification, after appropriate treatment with particular stains, such as hæmatoxylin, safranin, and other basic dyes, the nuclear fibres are shown to be composed of minute irregular masses of a deeply colored substance, appropriately

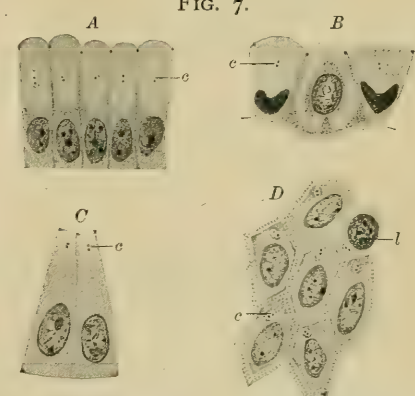
called *chromatin* in recognition of its great affinity for certain stains; the chromatin particles are supported upon or within delicate inconspicuous and almost colorless threads of *linin*. The latter, therefore, forms the supporting net-work of the nuclear fibrils in which the chromatin is so prominent by virtue of its capacity for staining. The forms of the individual masses of chromatin vary greatly, often being irregular, at other times thread-like or beaded in appearance. Not infrequently the chromatin presents spherical aggregations which appear as deeply stained nodules attached to the nuclear fibres; these constitute the false nucleoli, or *karyosomes*, as distinguished from the true nucleolus which is frequently present within the karyoplasm. Chemically, chromatin, the most essential part of the nucleus, contains *nuclein*, a compound rich in phosphorus.

The *matrix*, or *nuclear juice*, which occupies the interstices of the net-work, possesses an exceedingly weak affinity for the staining reagents employed to color the chromatin, and usually appears clear and untinted. It is probably closely related to the *achromatin* and contains a substance described as *paralinin*.

The *nucleolus*, or *plasmosome*, ordinarily appears as a small spherical body—sometimes multiple—lying among, but unattached to, the nuclear fibres; its color in stained tissues varies, sometimes resembling that of the chromatin, although less deeply stained, but usually presenting a distinct difference of tint, since it responds readily to dyes which, like eosin or acid fuchsin, particularly affect the linin and cytoplasm. Concerning the exact nature, purpose, and function of the nucleolus much uncertainty still exists; according to certain authorities, these bodies are to be regarded as storehouses of substances which are used in the formation of the chromatin segments during division, while other cytologists attribute to the nucleolus a passive rôle, even regarding it as by-product which, at least in some cases, is cast out from the nucleus into the cytoplasm, where it degenerates and disappears. Since trustworthy observations may be cited in support of both of these conflicting views, definite conclusions regarding the exact nature of this constituent of the nucleus must be deferred. The nucleolus is credited with containing a peculiar substance known as *pyrenin*. The term *amphipyrenin*, as applied to the substance of the nuclear membrane, is of doubtful value.

The Centrosome.—In addition to the parts already described, which are conspicuous and readily seen, the more recent investigations into the structure of cells show the presence of a minute body, the *centrosome*, which plays an important rôle in elements engaged in active change, as conspicuously during division and, in a lesser degree, during other phases of cellular activity. Ordinarily the centrosome escapes attention because, on account of its minute size and variable staining affinity, it is with difficulty distinguished from the surrounding particles. Its usual position is within the cytoplasm, but the exact location of the centrosome seems to depend upon the focus of greatest motor activity, since, as shown by Zimmermann, this little body, or bodies, being often double, is always found in that part of the cell which is the seat of greatest change; thus, in a dividing element, the centrosome lies immediately related to the actively changing nucleus, while within ciliated epithelium it is removed from the nucleus and is found closely associated with the contractile filaments which probably produce the movements of the hair-like appendages. In recognition of the intimate relations between this minute body and the active motor changes affecting the morphological constituents of the cell, the centrosome may be regarded physiologically as its dynamic centre; the name *kinocentrum* has been suggested by Zimmerman as best expressing this probable function of the centrosome. This little body is frequently surrounded by a clear

FIG. 7.



Centrosomes (*c*, *c*) in human epithelium; *A*, *B*, cells from gastric glands; *C*, from duodenal glands; *D*, from tongue; *l*, leucocyte with centrosome × 625. (*K. W. Zimmermann.*)

area or halo, the *centrosphere* or the *attraction sphere*, within which it appears as a minute speck, frequently being double instead of single.

In recapitulation, the chief constituents of the animal cell may be tabulated as follows :

- PROTOPLASM
  - Cytoplasm
    - Meshwork—*Spongioplasm*.
    - Ground-substance—*Hyaloplasm*, containing inclusions, *Metaplasm*.
  - Centrosome
  - Nucleus
    - Nuclear reticulum consisting of
      - *Linin* fibrils.
      - *Chromatin* (containing *Nuclein*).
    - Nuclear matrix (containing *Paralinin*).
    - *Nucleolus* (containing *Pyrenin*.)
    - *Nuclear membrane*.

DIVISION OF CELLS.

Disregarding for the present, at least, the occurrence of direct fission as a means of producing new elements observed among the simplest forms of animal life,

FIG. 8.

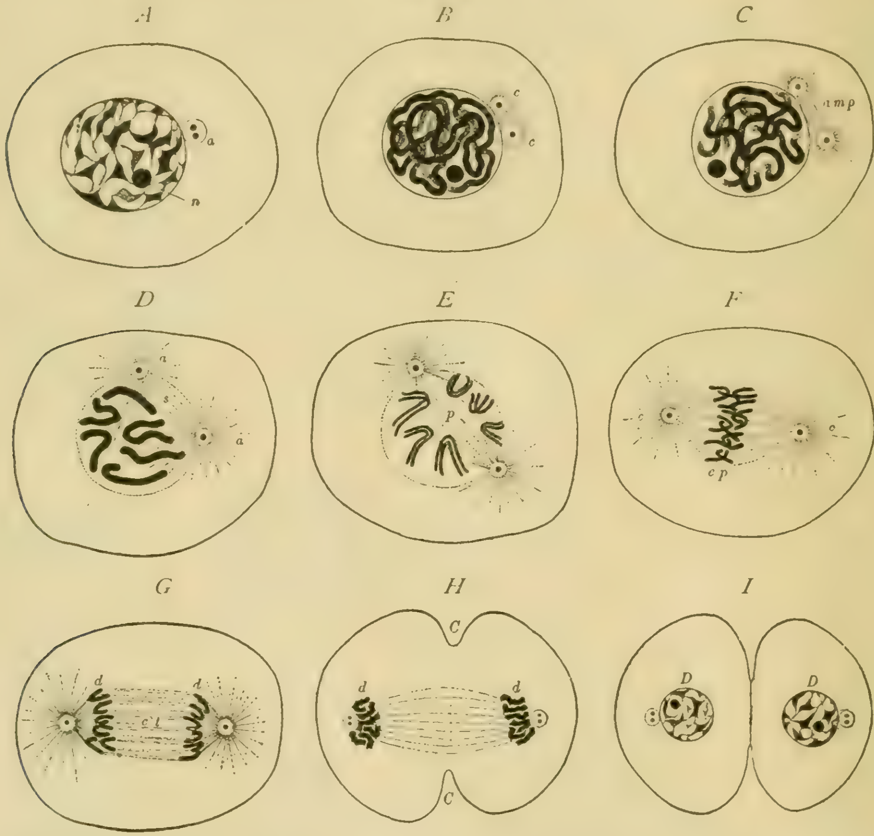


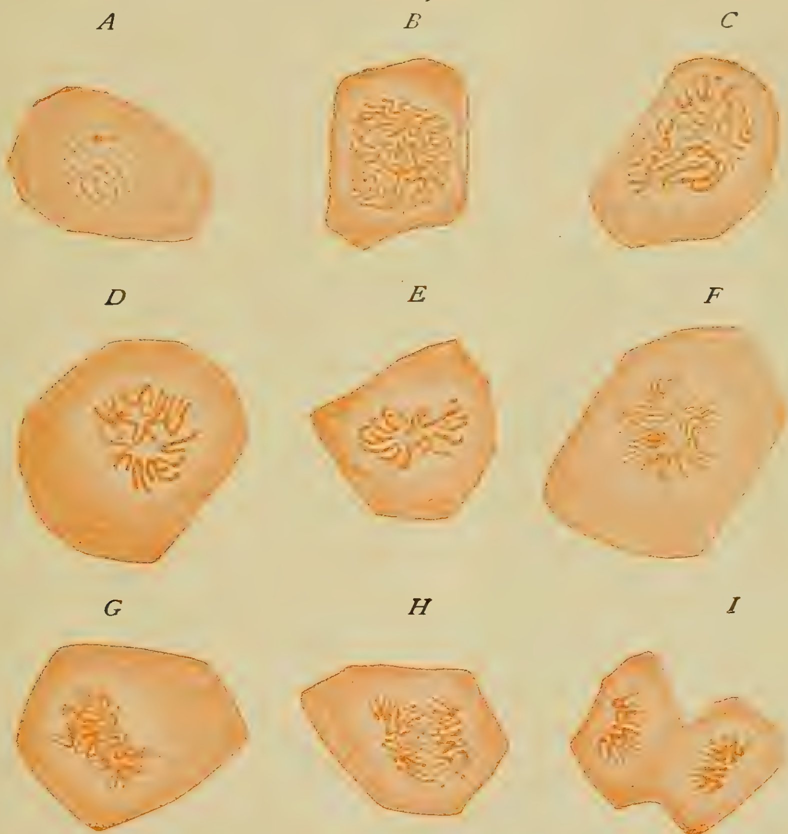
Diagram of mitosis. *A*, resting stage, chromatin irregularly distributed in nuclear reticulum; *a*, centrosphere containing double centrosome; *n*, nucleolus. *B*, chromatin arranged as close spirem; *c*, *c*, centrosomes surrounded by achromatic radial striations. *C*, stage of loose spirem, achromatic figure forming amphiaster (*amp*). *D*, chromatin broken into chromosomes; nucleolus has disappeared, nuclear membrane fading; amphiaster consists of two asters (*a*, *a*) surrounding the separating centrosomes, connected by the spindle (*s*). *E*, longitudinal cleavage of the chromosomes which are arranged around the polar field (*p*) occupied by the spindle. *F*, migration of chromatic segments towards new nuclei, as established by centrosomes (*c*, *c*); *e p*, equatorial plate formed by intermingling segments. *G*, separating groups of daughter chromosomes (*d*, *d*) united by connecting threads (*c t*). *H*, daughter chromosomes (*d*, *d*) becoming arranged around daughter centrosomes which have already divided; *C*, *C*, beginning cleavage of cytoplasm across plane of equatorial spindle. *I*, completed daughter nuclei (*D*, *D*); cytoplasm almost divided into two new cells. (*Modified from Wilson*).

or as an exceptional method among effete and diseased cells of the higher types, the production of new generations of cells may be assumed as accomplished for all

varieties of elements by a complicated series of changes, collectively known as *karyokinesis*, or *mitosis*, especially affecting the nucleus. As already pointed out, in addition to presiding over the nutritive and chemical changes, the nucleus is particularly concerned in the process of reproduction; further, of the several morphological constituents of the nucleus, the chromatin displays the most active change, since this substance is deeply concerned in transmitting the characteristics of the parent cell to the new elements. So essential is this substance for the perpetuation of the characteristics of each specific kind of cell that the entire complex mitotic cycle has for its primary purpose the insurance of the equal division of the chromatin of the mother cell between the two new nuclei, such impartial distribution of the chromatin taking place irrespective of any, or even very great, dissimilarity in the size of the daughter cells, the smaller receiving exactly one-half of the maternal chromatin.

Mitotic Division.—The details of karyokinesis, or mitosis, sometimes also spoken of as *indirect division*, include a series of changes involving the centrosome,

FIG. 9.



Chromatic figures in dividing cells from epidermis of salamander embryo. × 960. *A*, resting stage; *B*, close spireme; *C*, loose spireme; *D*, chromosomos (" wreath "), seen from surface; *E*, similar stage, seen in profile; *F*, longitudinal cleavage of chromosomes; *G*, beginning migration of segments towards centrosomes; *H*, separating groups of daughter segments; *I*, daughter groups attracted towards poles of new nuclei, cytoplasm exhibits beginning cleavage.

the nucleus, and the cytoplasm, which are conveniently grouped into four stages; (1) the *Prophases*, or preparatory changes; (2) the *Metaphase*, during which the chromatin is equally divided; (3) the *Anaphases*, in which redistribution of the chromatin is accomplished; (4) the *Telophases*, during which the cytoplasm undergoes division and the daughter cells are completed.

In anticipation of the consideration of the details of mitosis, it should be pointed out that the process includes two distinct, but intimately associated and coincident series of phenomena, the one involving the chromatin, the other the centrosomes and the linin. While as a matter of convenience these two sets of changes are described separately, it must be understood that they take place simultaneously and in coördination. The purpose of the changes affecting the chromatin is the accurate and equal division of this substance by the longitudinal cleavage of the chromatin segments ; the object of the activity of the centrosomes and the linin is to supply the requisite energy and to produce the guiding lines by which the chromatin segments are directed to the new nuclei, each daughter cell being insured in this manner one-half of the maternal chromatin.

The Prophases, or preparatory stages, include a series of changes which involve the nuclear substances and the centrosomes and result in the formation of the *karyokinetic figure* ; the latter consists of two parts, (1) the deeply staining chromatin filaments, and (2) the achromatic figure, which colors but slightly if at all. The chromatin loses its reticular arrangement and, increasing in its staining affinities, becomes transformed into a closely convoluted thread or threads, constituting the "close skein ;" the filaments composing the latter soon shorten and thicken to form the "loose skein." The skein, or *spireme*, may consist of a single continuous filament, or it may be formed of a number of separate threads. Sooner or later the skein breaks up transversely into a number of segments or *chromosomes*, which appear as deeply staining curved or straight rods. A very important, as well as remarkable, fact regarding the chromosomes is their *numerical constancy*, since it may be regarded as established that every species of animal and plant possesses a fixed and definite number of chromosomes which appear in its cells ; further, that in all the higher forms the number is *even*, in man being probably twenty-four. During these changes affecting the chromatin the nucleolus, or plasmosome, disappears, and, probably, takes no active part in the karyokinesis ; the nuclear membrane likewise fades away during the prophases, the nuclear segments now lying unenclosed within the cell, in which the cytoplasm and the nuclear matrix become continuous.

Coincident with the foregoing changes, the centrosome, which by this time has already divided into two, is closely associated with phenomena which include the appearance of a delicate radial striation within the cytoplasm around each centrosome, thereby producing an arrangement which results in the formation of two stars or *asters*. The centrosomes early show a disposition to separate towards opposite poles of the cell, this migration resulting in a corresponding migration of the asters. In consequence of these changes, the retreating centrosomes become the foci of two systems of radial striation which meet and together form an achromatic figure known as the *amphiaster*, which consists of the two asters and the intervening *spindle*. Notwithstanding the observations which tend to question the universal importance of the centrosome as the initiator of dynamic change within the cell, as held by Van Beneden and Boveri, there seems to be little doubt that the centrosome plays an important rôle in establishing foci towards which the chromosomes of the new nuclei become attracted.

The *nuclear spindle*, which originates as part of, or secondarily from the amphiaster, often occupies the periphery of the nucleus, whose limiting membrane by this time has probably disappeared. The delicate threads of linin composing the nuclear spindle lie within an area, the *polar field*, around which the chromosomes become grouped. The chromosomes, which meanwhile have arisen by transverse division of the chromatin threads composing the loose skein, appear often as V-shaped segments, the closed ends of the loops being directed towards the polar field which they encircle. Owing to this disposition, when seen from the broader surface, the chromosomes constitute a ring-like group, sometimes described as the *mother wreath* ; the same segments, when viewed in profile, appear as a radiating group of fibrils known as the *mother star* ; the apparent differences, therefore, between these figures depend upon the point of view and not upon variations in the arrangement of the fibres.

The Metaphase includes the most important detail of karyokinesis,—namely, the *longitudinal cleavage* of the chromosomes, whereby the number of the latter is

doubled and the chromatin is equally divided. This division is the first step towards the actual apportionment of the chromatin between the new nuclei, each of which receives exactly one-half of the chromatin, irrespective of even marked inequality in the size of the daughter cells.

Meanwhile the centrosomes have continued to separate towards the opposite poles of the cell, where, surrounded by their attraction spheres, each forms the centre of the astral striation that marks either pole of the amphiaster, the nuclear spindle being formed by the junction of the prolonged and opposing striæ. The purpose of the achromatic figure is to guide the longitudinally divided chromosomes towards the new nuclei during the succeeding changes.

The Anaphases accomplish the migration of the chromosomes, each pair of sister segments contributing a unit to each of the two groups of chromosomes that are passing towards the poles of the achromatic spindle ; in this manner each new nucleus receives not only one-half of the chromatin of the mother nucleus, but also the same number of chromosomes that originally existed within the mother cell, the numerical constancy of the particular species being thus maintained.

Anticipating their passage towards the poles of the achromatic figure, the migrating chromatic segments, attracted by the linin threads, for a time form a compact group about the equator of the spindle known as the *equatorial plate*. As the receding segments pass towards their respective poles, the opposed ends of the separating chromosomes are united by intervening achromatic threads, the *connecting fibres*. Sometimes the latter exhibit a linear series of thickenings known as the *cell-plate* or *mid-body*. The migration of the chromosomes establishes the essential features of the division of the nucleus, since the subsequent changes are only repetitions, in inverse order, of the changes already noted.

The Telophases, in addition to the final stages in the rearrangement of the chromatic segments of the new nuclei, including the appearance of the daughter wreath, the daughter skeins, the new nuclear membrane, and the nucleolus, witness the participation of the cytoplasm in the formation of the new cells. In these final stages of mitosis the cell-body becomes constricted and then divides into two, the plane of division passing through the equator of the nuclear spindle. Each of the resulting masses of cytoplasm invests a new nucleus and receives one-half of the achromatic figure consisting of a half-spindle and one of the asters with a centrosome. The new cell, now possessing all the constituents of the parent element, usually acquires the morphological characteristics of its ancestor and passes into a condition of comparative rest until called upon, in its turn, to enter upon the complicated cycle of mitosis.

MITOTIC DIVISION.

I. Prophases.

A. *Changes within the nucleus : Chromatic figure.*
- Chromatin loses reticular arrangement,
- Close skein,
- Loose skein,
- Disappearance of nucleolus,
- Division of skein into chromosomes,
- Arrangement around polar field—mother wreath,
- Disappearance of nuclear membrane.

B. *Changes within the cytoplasm : Achromatic figure.*
- Division of centrosome,
- Appearance of asters,
- Migration of centrosomes,
- Appearance of spindle,
- Formation of amphiaster,
- Appearance of nuclear spindle and polar field.

II. Metaphase.

Longitudinal cleavage of chromosomes,

III. Anaphases.

Rearrangement of chromosomes into two groups,
Migration of groups towards poles of amphiaster.
Appearance of connecting fibres between receding groups,
Construction of daughter nuclei.

IV. Telophases.

Constriction of cell-body appears at right angles to spindle,
Chromosomes rearranged in daughter nuclei to form skeins,
Reappearance of nuclear membrane,
Reappearance of nucleoli,
Complete division of cell-body,
Daughter nuclei assume vegetative condition,
Achromatic striation usually disappears,
Centrosomes, single or divided, lie beside new nuclei.

AMITOTIC DIVISION.

The occurrence of cell reproduction without the foregoing complex cycle of karyokinetic changes is known as *amitotic* or *direct division*. That this process does take place as an exceptional method in the reproduction of the simplest forms of animal life, or in the multiplication of cells within pathological growths or tissues of a transient nature, as the fœtal envelopes, may be regarded as established beyond dispute.

Fig. 10.

Decidual cells showing amitotic division of nucleus (*A-D*); in *E* an attempt at mitosis has occurred. × 410.

The essential difference between amitotic and the usual method of division lies in the fact that, while in the latter the chromatin of the nucleus is equally divided and the number of chromosomes carefully maintained, in direct division the nucleus remains passive and suffers cleavage of its total mass, but not of its individual components. Since the nucleus remains in the vegetative condition, neither the chromatic nor achromatic figure is produced, the activity of the centrosome, when exhibited, being possibly directly expended in effecting a division of the cytoplasm, and incidentally that of the nucleus. In many cases the amitotic division of the nucleus is not accompanied by cleavage of the cytoplasm, such processes resulting in the production of multinuclear and aberrant nuclear forms. In general, it may be assumed that cells which undergo direct division are elements destined to suffer premature degeneration, since such cells subserve special purposes and are not capable of perpetuating their kind by normal reproduction. Flemming has pointed out the fact that those leucocytes which arise by amitotic division, and therefore deviate from the usual mode of origin of these elements, are cells which are doomed to early death; this form of cell-division among the higher forms must be regarded, probably, as a secondary process.

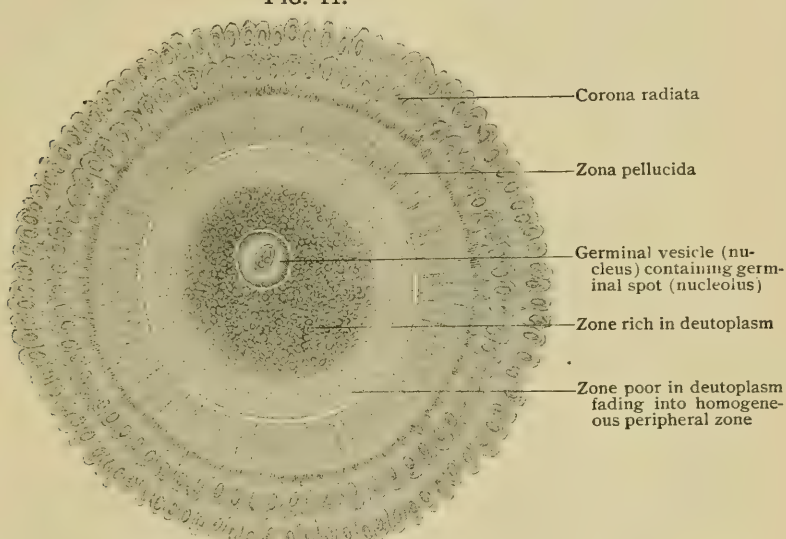
EARLY DEVELOPMENT.

THE human body with all its complex organism is the product of the differentiation and specialization of the cells resulting from the union of the parental sexual elements,—the ovum and the spermatozoon.

The Ovum.—The maternal germ-cell is formed within the female sexual gland, the ovary, in which organ it passes through all stages of its development, from the immature differentiation of its early condition to the partially completed maturation of the egg as it is liberated from the ovary.

The *human ovum*, in common with the ova of other mammals, is of minute size, being, as it is discharged from the ovary, about .25 millimetre in diameter. Examined microscopically and after sectioning, the human ovum is seen to be enclosed within a distinct envelope, the *zona pellucida*, .014 millimetre in thickness, which in favorable preparations exhibits a radial striation, and hence is also named the *zona radiata*. This envelope at first was confounded with the proper limiting membrane of the cell, and for a time was erroneously regarded as corresponding to the

FIG. 11.



Human ovum from ripe Graafian follicle. × 170. (*Nagel.*)

cell-wall. The nature of the zona pellucida is now generally conceded to be that of a protecting membrane, produced through the agency of cells surrounding the ovum.

The substance of the ovum, the yolk, or *vitellus*, consists of soft, semifluid protoplasm modified by the presence of innumerable yolk-granules, the representatives of the important stores of nutritive materials present in the bird's egg. Critically examined, the vitellus is resolvable into a reticulum of active protoplasm, or *oöplasm*, and the nutritive substance, or *deutoplasm*. At times the yolk is limited externally by a very delicate envelope, the *vitelline membrane*, which usually lies closely placed, or adherent, to the protecting zona radiata; sometimes, however, it is separated from the latter by a *perivitelline space*. The vitelline membrane is probably absent in the unfertilized human ovum.

A large spherical nucleus, the *germinal vesicle*, approximately .037 millimetre in diameter, usually lies eccentrically within the yolk, surrounded by the distinct nuclear membrane. Within the germinal vesicle the constituents common to nuclei in

general are found, including the all-important chromatin fibrils, nuclear matrix, and nucleolus; the latter, in the original terminology of the ovum, is designated as the *germinal spot*, and measures about .005 millimetre in diameter. In addition to these more easily distinguished components of the maternal cell, the centrosome must be accepted as a constant constituent of the fully formed, but unmatured, ovum, although its presence may escape detection.

The Spermatozoon.—The male germ-cell, the spermatic filament, is produced by the specialization of epithelial elements lining the seminiferous tubules within the testicle. The human spermatozoon consists of three parts—the ovoid *head*, the cylindrical *middle-piece*, which includes the slightly-constricted *neck* and the *connecting-piece*, and the attenuated and greatly extended *tail*; of these, the head and middle-piece are the most important, since these parts contain respectively the chromatin and the centrosome of the cells from which the spermatic filaments are derived. The centrosome is represented by two minute spherical bodies, the *neck-granules*, which lie in the neck immediately beneath the head, at the extremity of the *axial fibre*; the latter extends throughout the spermatozoon from the head to the termination of the tail, ending as an extremely attenuated thread, the *terminal filament*. The tail corresponds to a flagellum and serves the purposes of propulsion alone, taking no part in the important changes produced in the ovum by the entrance of the male element.

FIG. 12.

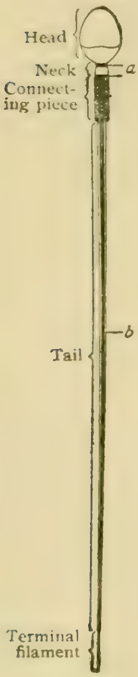


Diagram of human spermatozoon; *a*, neck-granules, representing the centrosome; *b*, axial fibre, × 1800. (*Meves*.)

Maturation of the Ovum.— Maturation, or ripening of the ovum, is that process by which the female element is prepared for the reception of the spermatozoon. It takes place, however, entirely independently of the influence of the male or of the probability of fertilization, every healthy ovum undergoing these changes before it becomes sexually ripe. About the time that the ovum is liberated from the ovary by the bursting of the Graafian follicle, as the sac which encloses the egg within the ovarian stroma is called, its nucleus engages in the complicated cycle already described as mitotic division. The nucleus migrates to the periphery of the ovum, loses its limiting membrane, and undergoes division, one pole of the nuclear spindle being located within the protrusion of protoplasm which has coincidently taken place. With the division of the nuclear chromatin, the protruded protoplasm becomes constricted and finally separated from the ovum; the minute isolated mass thus formed, containing one-half of the maternal chromatin, is the *first polar body*. Almost immediately the mitotic cycle is repeated, and again results in the constriction and final separation of a minute cell, the *second polar body*. These two isolated portions of the ovum remain visible for a long time as small, deeply stained cells lying within the perivitelline space beneath the zona pellucida. With each division of the egg-cell, one-half of the chromatin passes to the polar body, the matured ovum consequently retaining but one-fourth of the original chromatin. While the latter is thus diminished at each division, the masses of chromatin are reduced to one-half the normal quota of chromosomes, this *reduction* being effected just before the first polar division.

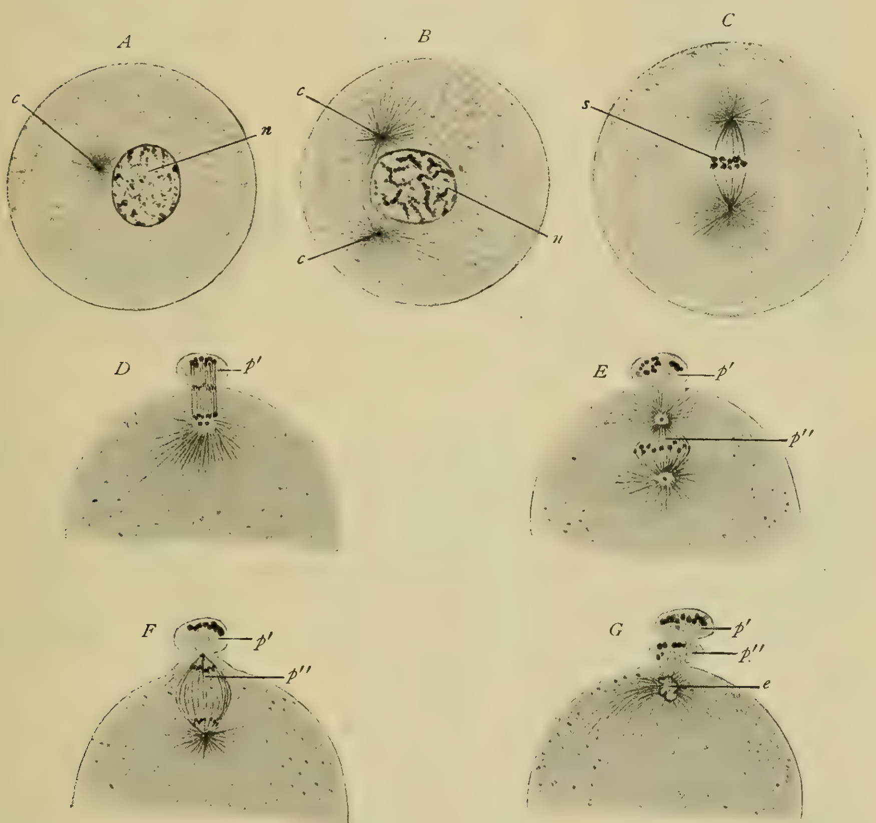
The chromatin remaining within the ovum after the repeated division becomes collected within a new nucleus, which now takes a non-central position within the egg, and is henceforth known as the *female pronucleus* or *egg-nucleus*. After maturation the ovum is prepared for union with the spermatozoon, although in many cases the male sexual element has actually entered the ovum before the completion of the maturation cycle: should, however, impregnation not occur, the ovum passes along the oviduct into the uterus and is finally lost. The passage of the human egg from the ovary to the uterus occupies, probably, about eight days, a period corresponding closely to the length of time that the ovum retains its capability of fertilization.

The significance of the extrusion of the polar bodies—a process which occurs

with great constancy in almost all animals, and, indeed, is probably represented in the development of vegetal organisms as well—has been the subject of much discussion and speculation. The most satisfactory explanation of the significance of maturation has been proposed by Van Beneden, Boveri, and others, based upon the comparison of the changes which take place in the development of the germ-cells of the two sexes.

In order to appreciate the necessity and the meaning of maturation of the ovum, it will be of advantage to take a brief survey of the phenomena attending the development of the male sexual elements. The seminiferous tubules of the testicle are lined with epithelial cells, certain of which, known as the *primary spermatocytes*,

FIG. 13.



Semi-diagrammatic representation of the formation of the polar bodies, based upon observations of invertebrate ova (*Ascaris* and *Physa*). *n*, nucleus; *c*, *c*, centrosomes; *s*, nuclear spindle; *p′*, *p″*, first and second polar bodies; *e*, egg-nucleus. (*After Kostanecki and Wierzejski.*)

increase in size and undergo division, the daughter cells constituting the *secondary spermatocytes*. Each of the latter, in turn, gives rise to a new generation, the *spermatids*, from which the spermatozoa are directly formed, the chromatin of the spermatid being stored within the head, and the centrosome forming the neck-granules within the middle-piece. The spermatozoon, therefore, represents the third generation and corresponds to the mature ovum.

Turning to the phenomena of maturation, a parallel process is presented, since the ovarian egg, or *primary oöcyte*, divides into two cells, the *secondary oöcytes*, represented by the ovum and the first polar body, each of which receives one-half of the chromatin, notwithstanding that one of the daughter cells, the first polar body, is disproportionately small; the repetition of division effects a second distribution of

the chromatin, so that the mature egg, after the completion of maturation, represents the third generation, and is, therefore, morphologically equivalent to a spermatozoon.

Attention has already been directed to the important fact that the cells of a given species contain a fixed, definite, and even number of chromosomes (page 12); hence, in their primary condition, each germ-cell contains the full complement of chromatin segments. Since, however, the new being arises from the elements derived from the segmentation of a cell to the nucleus of which both parents contribute an equal number of chromosomes, it follows that, unless some provision be made whereby the number of chromosomes in each germ-cell be reduced to one-half the full number, the elements of the new being would be provided with double the number required to satisfy the normal complement for the particular species. In fact, such *reduction* of the chromosomes of the germ-cells does take place during the development of these elements, in consequence of which the ovum and the spermatozoon each contribute only one-half the number of chromosomes, the normal quota being restored to the segmentation nucleus, and subsequently to the cells of the new being, by the sum of the contributions of both parents.

FIG. 14.

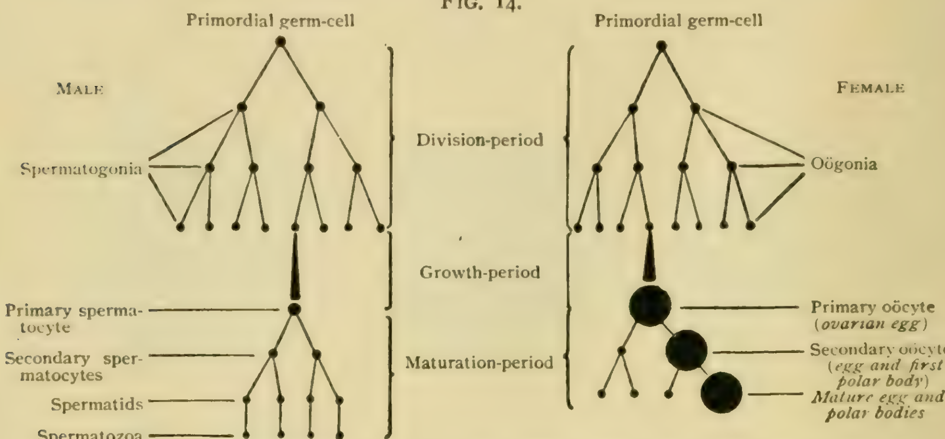


Diagram illustrating the genesis of the male and female germ-cells. (*After Boveri.*)

Interpreted in the light of these considerations, maturation may be regarded as the means by which correspondence between the sexual cells is secured, and, further, the polar bodies may be considered as abortive ova.

Fertilization of the Ovum.—Impregnation, or fertilization of the ovum, includes the meeting of the male and female elements, the penetration into the substance of the latter by the former, and the changes immediately induced by the presence of the spermatozoon within the egg.

Coincidently with the rupture of the distended Graafian follicle, the surface of the ovary is embraced by the expanded fimbriated extremity of the oviduct, along the plications of which the liberated matured ovum is guided into the tube. It is highly probable that not an inconsiderable number of the ova discharged from the ovary fail to reach the oviduct and are lost in the abdominal cavity.

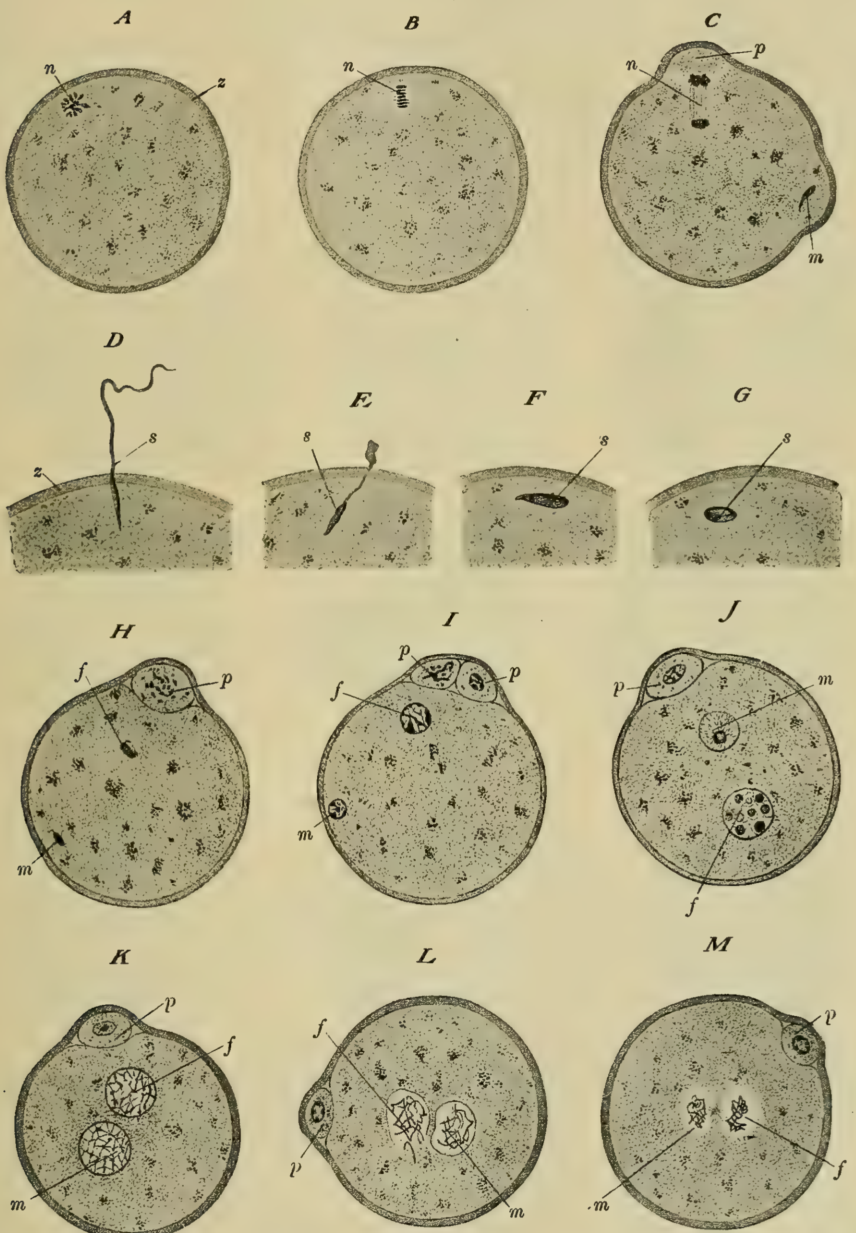
Recent investigations have shown that both germ-cells contain particular *accessory chromosomes*, which are probably important factors in the determination of the sex of the new being.

The spermatozoa overcome the obstacles offered within the narrow channels by the mucus and the opposed ciliary currents of the uterine and tubal mucous membranes by virtue of their long actively vibrating tails, and advance at a rate estimated at from 1.5 to 2.5 millimetres per minute; it is therefore probable that the seminal cells accomplish the journey from the mouth of the uterus to the ovum in from eight to ten hours. Spermatozoa retain their vitality and fertilizing powers for many days within the normal female genital tract; repeated observation on the human subject has shown that this period may extend throughout an entire

menstrual cycle of twenty-eight days,—a possibility to be remembered when calculating the probable termination of pregnancy.

Of the many millions of spermatic elements deposited within the vagina, only

Fig. 15.



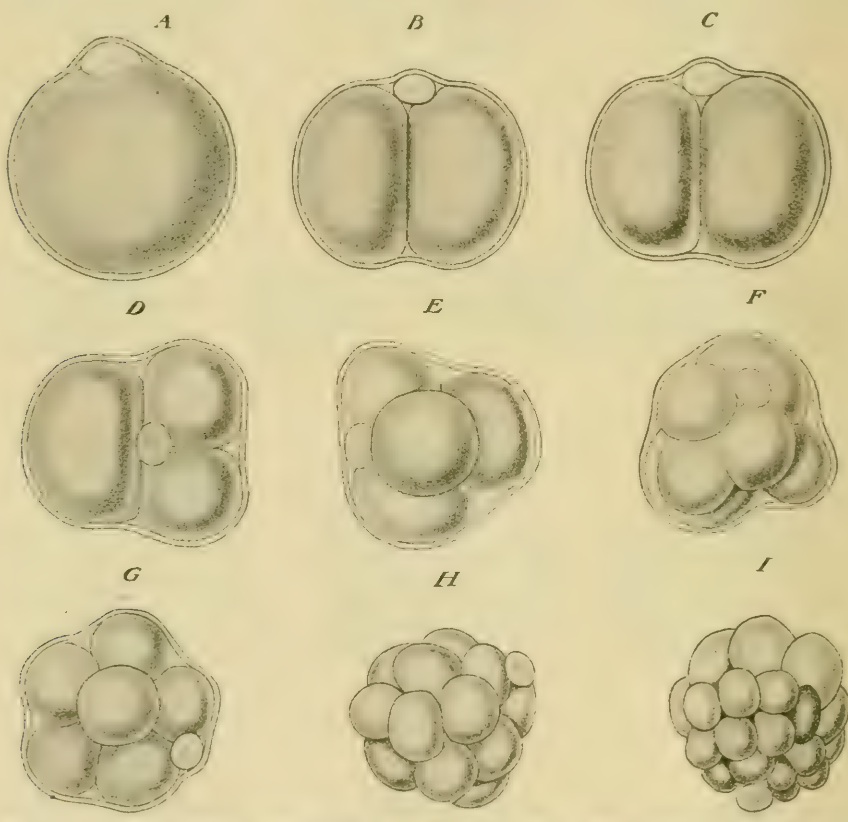
Fertilization of the ovum as illustrated by sections of the eggs of the mouse. (*Sobotta.*) All the figures are magnified 437 diameters except *D–G*, in which the amplification is 1310 diameters. *A–C*, prophases of formation of first polar body (*p*); *z*, zona pellucida; *n*, nuclear figure; *m*, head of spermatozoon. *D–G*, entrance of spermatozoon (*s*) into ovum and subsequent changes. *H–M*, sequence of changes during the formation, approach, and blending of the male (*m*) and female (*f*) pronuclei; *p*, *p*, polar bodies.

an insignificant number ever reach the vicinity of the ovum. Notwithstanding that probably a number of spermatozoa penetrate the zona pellucida, normal fertilization in man and the higher animals is effected by a single seminal element. After

the entrance of the favored spermatozoon into the substance of the ovum, an effectual barrier to the penetration of additional seminal cells is presented by the thick vitelline membrane which immediately forms. The point at which the spermatozoon is about to enter the egg is indicated by a conical elevation, the *receptive eminence*, into which the male germ-cell sinks,—the tail only partly entering the protoplasm of the egg and very soon disappearing.

The position of the remains of the spermatozoon within the substance of the ovum is indicated by an ovoid body, the *male pronucleus*, which contains the chromatin and centrosome of the paternal germ-cell. The *sperm-nucleus* and the *egg-nucleus*, as the male and female pronuclei are now often designated, usually break up into their respective chromosomes without fusing into a single segmentation

FIG. 16.



Early stages of segmentation as seen in ova of mouse, surface view. × 450. (*Sobotta.*) The external double contour represents the zona pellucida; the cell marked with ×, the polar body. *A*, fertilized ovum at stage of the pronuclei; *B*, two segmentation spheres of equal size; *C*, segmentation spheres of unequal size; *D*, three-cell stage resulting from division of larger sphere; *E*, stage of four spheres; *F*, six; *G*, eight; *H*, sixteen; *I*, twenty-five.

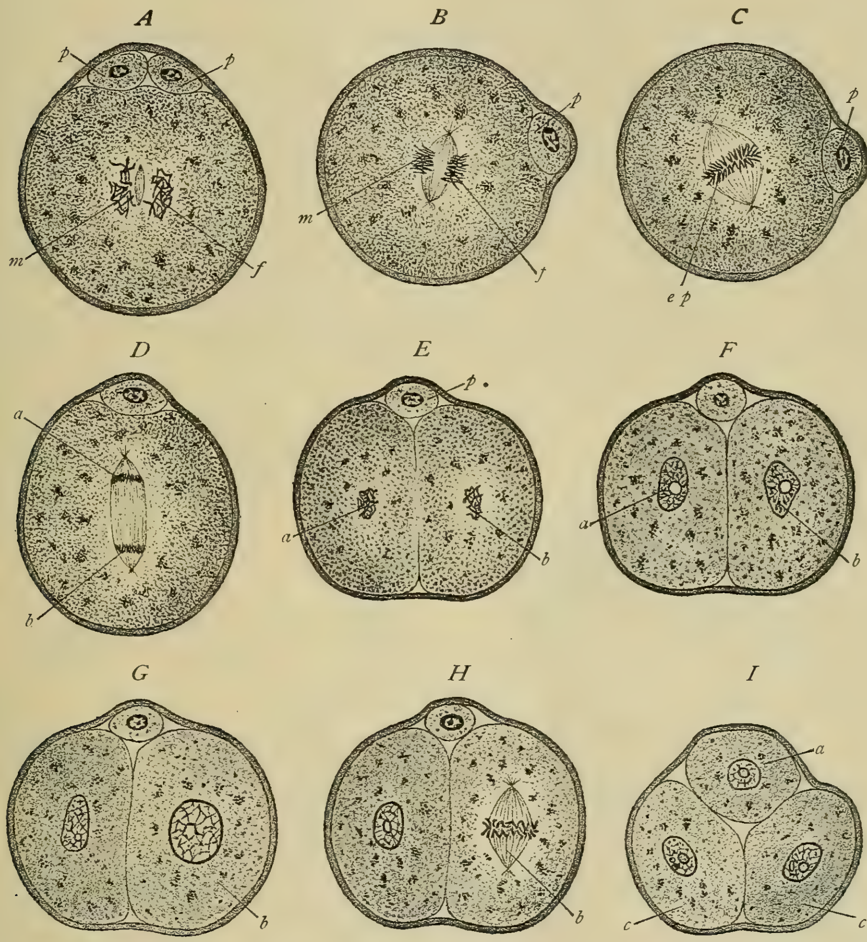
nucleus. In this case the two groups of chromosomes unite in the first mitotic figure, the segmentation spindle (Fig. 17).

After the fusion of the pronuclei, and just as segmentation is beginning, the fertilized ovum presents a clear oval area which contains the two groups of chromosomes contributed by the germ-cells of both parents; on opposite sides of the chromatin figure are the centrospheres, each containing a centrosome and surrounded by a marked polar striation within the substance of the egg. The centrosomes now present within the ovum are usually both derived from the substance of the centrosome of the spermatid, which entered the ovum as the neck-granules within the middle-piece of the fertilizing spermatozoon. The rôle of the latter, therefore, is two-fold,—to contribute the chromatin necessary to restore to the parent cell the normal

complement of chromosomes, and to furnish the stimulus required to inaugurate the karyokinetic cycle of segmentation.

Segmentation of the Ovum.—The union of the male and female pronuclei and the resulting formation of the segmentation nucleus is followed immediately by the division of the ovum into two new elements ; each of these gives rise to two additional cells, which, in turn, produce following generations of segmentation cells, or *blastomeres*. This process of repeated division of the fertilized ovum and its

FIG. 17.



Early stages of segmentation as seen in sections of ova of mouse. × 500. (*Sobotta.*) *A–D* show the rearrangement of the chromosomes contributed by the male (*m*) and female (*f*) pronuclei as preparatory to the first cleavage of the fertilized ovum; *p*, *p*, polar bodies; *e p*, stage of equatorial plate; *a*, *b*, daughter groups of chromosomes. *E*, *F*, the daughter cells arising from first cleavage. *G*, one cell (*b*) is larger and is preparing to divide. *H*, later stage of this division. *I*, stage of three segmentation spheres (*a* and *c*, *c*) resulting from this division.

descendants constitutes *segmentation*,—a process common to the development of all animals and plants above the very simplest.

Study of the details of segmentation in the various classes of animals shows that a close relation exists between the character of the cleavage and that of the ovum with regard to the amount and distribution of the nutritive yolk, or deutoplasm, present.

In the human and mammalian egg the nutritive yolk particles are comparatively meagre and are uniformly distributed throughout the vitellus ; in such eggs there is no aggregation of the food particles, hence such ova are termed *homolecithal* or with a homogeneous yolk. In the eggs of birds, reptiles, and fishes, on the con-

trary, the deutoplasm, or nutritive material, is collected towards one pole of the egg, while the protoplasm, or formative material, is limited to the other ; eggs in which these conditions obtain possess a distinctly polar yolk, and hence are known as *telolecithal* ova. These aggregations of the protoplasm and the deutoplasm constitute respectively the *formative* and the *nutritive* yolk, and correspond in position to the *animal* and the *vegetative* poles of the egg. In an additional class of eggs, the *centrolecithal*, the yolk occupies the centre of the ovum, being covered by a peripheral zone of formative material ; since such ova belong alone to certain insects and are not found among vertebrates, they possess limited interest to students of mammalian forms.

Comparison of the behavior of these various groups of ova during segmentation shows that only eggs poor in deutoplasm, as the alecithal mammalian and amphibian ova, undergo complete cleavage during segmentation, those of the bird, reptile, and fish undergoing cleavage only within the formative yolk. Ova, therefore, are classified according to the completeness of their division into those exhibiting *complete segmentation* and those undergoing *partial segmentation ;* the former are known as *holoblastic*, the latter as *meroblastic*. The embryologist further recognizes an *equal* and an *unequal* complete segmentation according to the equality or inequality of the cells, or blastomeres, resulting from the division of the ovum. Since the segmentation spheres derived from the mammalian egg may be regarded as practically of equal size, the egg of this class of animals, including the human ovum, is described as an *homolecithal holoblastic ovum*, undergoing *equal segmentation*. It must be understood, however, that even in the segmentation of such ova

FIG. 18.

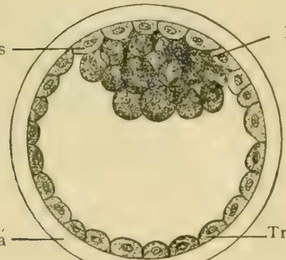


Diagram of early mammalian blastodermic vesicle, consisting of trophoblast and inner cell-mass. (*After Van Beneden.*)

FIG. 19.

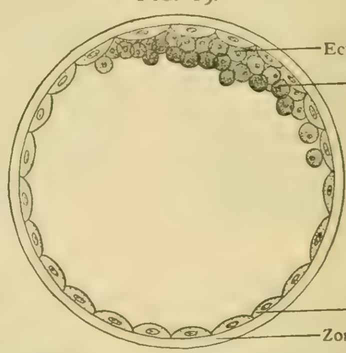


Diagram of mammalian blastodermic vesicle ; inner cells differentiating into ectoblast and entoblast. (*After Van Beneden.*)

the blastomeres very early exhibit inequality in size and in rapidity of division (Fig. 16), the effect of this differentiation being, that the more rapidly multiplying blastomeres are smaller than the more slowly dividing elements. It is of interest, in this connection, to note that the purest type of total equal segmentation is observed in the ovum of the lowest vertebrate, the amphioxus,—an animal whose development has shed much light on many obscure problems in the embryology of the higher forms, including mammals and even man.

The meroblastic bird's egg, on the contrary, undergoes cleavage only within a limited circular field at its animal pole ; it is said, therefore, to undergo *partial discoidal* segmentation. In contrast to this, the centrolecithal ova exhibit partial *superficial* segmentation, the peripheral zone of formative material alone undergoing cleavage.

The Blastoderm and the Blastodermic Layers.—The completion of segmentation in holoblastic ova results in the production of a mass of blastomeres, which is a solid sphere composed of mutually compressed segmentation cells ; to this sphere the older anatomists gave the name of the *morula*, or the mulberry mass. The solidity of the morula is temporary, since a cavity is soon developed within it. This cavity, often called the *segmentation cavity*, increases to such an extent that a

hollow sac is formed, walled by a single layer of cells, at one point on the inner surface of which is attached a small mass of cells. The outer, covering layer of cells is known as the *trophoblast*; the small group of cells attached to the inner surface of the trophoblast is known as the *inner cell-mass* (Fig. 18). Examined from the surface, this aggregation of inner cells appears as an opaque circular field, the ***embryonic area***, due to the increased thickness and consequently diminished transparency of the wall of the blastodermic vesicle at the place of attachment of the included cells. In the purest type of the blastodermic vesicle, that seen in the amphioxus (Fig. 26, *A*), the sac consists of a single layer of blastomeres of almost uniform size; the mammalian blastodermic vesicle, however, presents greater complexity, due to the unequal rate at which some of the segmentation cells divide and to the rapid increase in the size of the vesicle.

The inner mass of germinal cells soon undergoes differentiation (Fig. 19) into two strata,—an outer layer, closely applied to the trophoblast, and an inner layer. These layers are respectively the *ectoblast* and the *entoblast*,—two of the three great primary *blastodermic layers* from which the embryo is differentiated.

Coincidently with the formation of these germinal layers, the mammalian blastodermic vesicle grows with great rapidity, increasing from a sphere of microscopic size to a vesicle of one or more millimetres in diameter. In consequence of this growth, the trophoblast undergoes great expansion, its cells becoming reduced to flattened elements, which, over the embryonic area, later disappear. In some animals, as in the rabbit, the flattened trophoblast cells extend over the embryonic ectoblast and have been called the *cells of Rauber*. In such cases, therefore, the ectoblast is overlaid within the embryonic area by the cells of Rauber, but at the margin of the area, the embryonic ectoblast is continuous with the trophoblast forming the outer layer of the wall of the blastodermic vesicle. With the subsequent expansion of the blastodermic vesicle, the cells of Rauber disappear from the surface of the embryonic ectoblast, which then lies upon the surface of the vesicle (Figs. 20, 21).

FIG. 20.

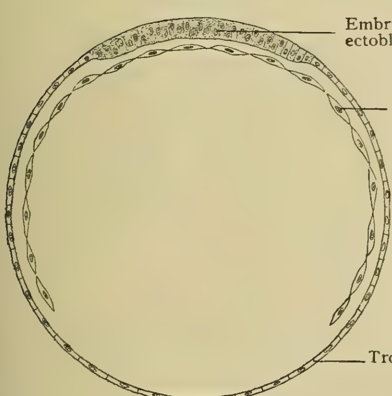


Diagram of mammalian blastodermic vesicle; the entoblast forms an almost complete inner layer.

FIG. 21.

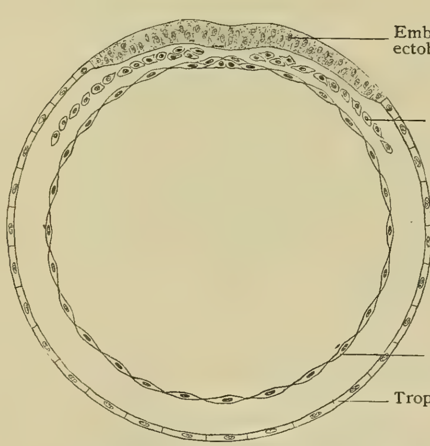


Diagram of mammalian blastodermic vesicle; the mesoblast is just appearing as the third blastodermic layer.

The early blastodermic vesicle at first consists of only two primary layers, the ectoblast and the entoblast; this stage of development is appropriately termed that of the *bilaminar blastoderm* (Fig. 20); a little later, a third layer, the *mesoblast*, makes its appearance between the outer and inner blastodermic sheets; this stage is designated as that of the *trilaminar blastoderm* (Fig. 21).

The early embryo, shortly after the formation of the blastodermic vesicle, consists of three layers of cells,—the ectoblast, the mesoblast, and the entoblast. The histological characters of the outer and inner of these primary layers differ, almost

from the first, from those of the mesoblast, their component elements being more compact in arrangement and early manifesting a tendency to acquire the characteristics of covering cells or epithelium.

The mesoblastic elements, on the contrary, soon assume irregular forms and are loosely held together by intercellular substance, thus early foreshadowing the special features which distinguish the subsequently differentiated connective tissues. This early distinction becomes more marked as differentiation proceeds, the epithelial tissues possessing elements of comparatively regular form, separated by minute amounts of intercellular substance ; the latter in the connective tissues, on the contrary, becomes conspicuous on account of its excessive quantity and the resulting profound modifications in the physical character of the tissue; the cells of the connective tissues rapidly assume the irregularly stellate or triangular form so characteristic in young tissues of this class. Since the three primary layers give rise to all the tissues of the organism, a brief synopsis presenting these genetic relations here finds an appropriate place.

DERIVATIVES OF THE BLASTODERMIC LAYERS.

From the **ectoderm** are derived—

- The epithelium of the outer surface of the body, including that of the conjunctiva and anterior surface of the cornea, the external auditory canal, together with the epithelial appendages of the skin, as hair, nails, sebaceous and sweat-glands (including the involuntary muscle of the latter).
- The epithelium of the nasal tract, with its glands, as well as of the cavities communicating therewith.
- The epithelium of the mouth and of the salivary and other glands opening into the oral cavity.
- The enamel of the teeth.
- The tissues of the nervous system.
- The retina ; the crystalline lens, and perhaps part of the vitreous humor.
- The epithelium of the membranous labyrinth.
- The epithelium of the pituitary and pineal bodies.

From the **mesoderm** are derived—

- The connective tissues, including areolar tissue, tendon, cartilage, bone, dentine of the teeth.
- The muscular tissues, except that of the sweat-glands and dilator pupillæ.
- The tissues of the vascular and lymphatic systems, including their endothelium and circulating cells.
- The sexual glands and their excretory passages, as far as the termination of the ejaculatory ducts and vagina.
- The kidney and ureter.

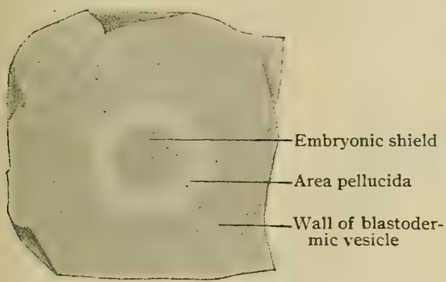
From the **entoderm** are derived—

- The epithelium of the digestive tract, with that of all glandular appendages except those portions derived from ectodermic origin at the beginning (oral cavity) and termination of the tube.
- The epithelium of the respiratory tract.
- The epithelium of the urinary bladder and urethra.
- The epithelium of the thyroid and thymus bodies, the modified primary epithelium of the latter giving rise to Hassall's corpuscles.

The Primitive Streak and the Gastrula.—Examined from the surface during the formation of the primary layers, the mammalian blastodermic vesicle, as represented by that of the rabbit, presents a circular light-colored field, the *embryonic area*, which corresponds to the expansion of the original embryonic spot, the latter becoming larger with the extension of the ectoblast and the entoblast differentiated from the inner cell mass. At first circular, the embryonic area later becomes oval or pyriform in outline (Figs. 22, 23), the larger end corresponding with the cephalic

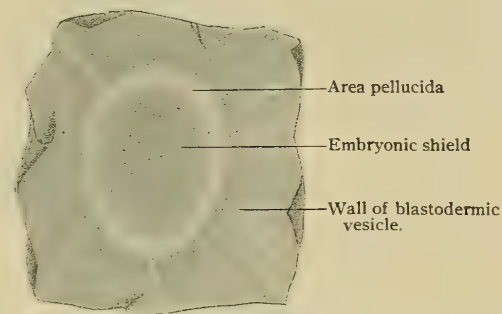
pole of the future embryo. In consequence of the proliferation of the ectoblastic cells, the embryonic area becomes differentiated into a central field, the *embryonic shield*, and a peripheral zone, the *area pellucida*, which by transmitted light appear respectively dark and light, owing to the varying transparency of the thicker central and thinner peripheral portions of the germinal field.

FIG. 22.



Embryonic area of rabbit of about six and one-half days, seen from the surface by transmitted light. × 26. (*Kollmann.*)

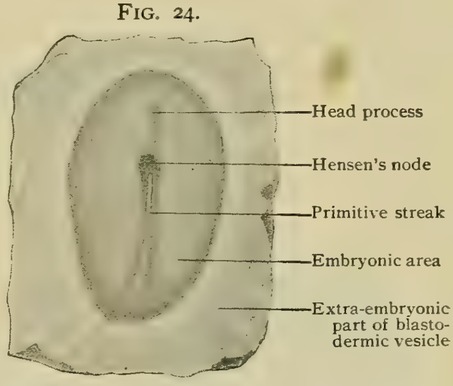
FIG. 23.



Embryonic area of rabbit of about seven days, seen from the surface. × 26. (*Kollmann.*)

Coincidently with the assumption of the oval or pyriform outline, a linear thickening of ectoderm appears towards the smaller end of the embryonic area. This is the *primitive streak*, which grows backward from a terminal thickening, the *node of Hensen*, that marks its anterior extremity. The primitive streak indicates the direction of the longitudinal axis of the future embryo and is modelled by a shallow furrow, the *primitive groove*, due to the proliferation of the surrounding ectoderm. From the sides of the primitive streak cells are budded off to form the mesoderm, which grows between the outer and inner germ-layers until it, finally, surrounds the blastodermic vesicle. At first, the mesoblast extends laterally and posteriorly and, later, grows forward as two lateral wings, that embrace the head-end of the embryonic area. While for a time attached only to the ectoderm, the primitive streak subsequently fuses with the entoderm, so that sections across the streak show all the germ-layers blended. The primitive streak is a transient organ and later entirely disappears; it contributes, however, the rapidly growing mesoblastic tissue, which later becomes related to the anal region and the tail-bud.

FIG. 24.



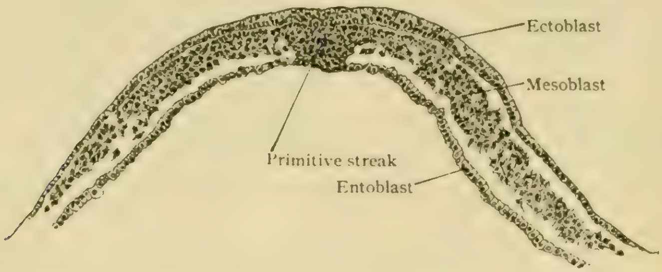
Embryonic area of rabbit of about eight days, seen from the surface. × 20. (*After Van Beneden.*)

The Significance of the Primitive Streak and the mode of formation of the mesoblast are vexed problems in embryology. A brief note on this topic will suffice here. In amphioxus, the lowest vertebrate, the immediate result of segmentation is a hollow sphere, the *blastula*, filled with fluid, lined by a single layer of cells. Invagination at one point of the wall of the blastula occurs, forming eventually a two-layered cup, the *gastrula*, the outer layer of which is the ectoblast, and the inner one the entoblast. The cavity within the entoblast is the *archenteron* or primitive gut. The opening into the archenteron is the *blastopore*. Cells given off from the entoblast, near the blastopore, form a third layer, the mesoblast. Typical gastrulation does not occur in the higher animals, although in the early human embryo a canal appears, known as the *neurenteric canal*, the opening of which is often regarded as homologous with the blastopore. The primitive streak is regarded by some authorities, notably Hertwig, as an elongated blastopore with lips fused. Since the primitive streak, the product of the outer germ-layer, is the principal primary source of the mesoblast, the latter may be regarded as indirectly derived from the ectoblast. A limited secondary and later production of mesoblast is attributed by some to the inner germ-layer.

THE FUNDAMENTAL EMBRYOLOGICAL PROCESSES.

Shortly after the appearance of the primitive streak—a structure, it will be remembered, which is transient and only indirectly takes part in the formation of the embryo proper—a series of phenomena mark the earliest stages of the future new being. These changes are known as the *fundamental embryological processes*, and result in the formation of the neural canal, the notochord, and the somites. While described for convenience as separate processes, they progress to a great extent simultaneously.

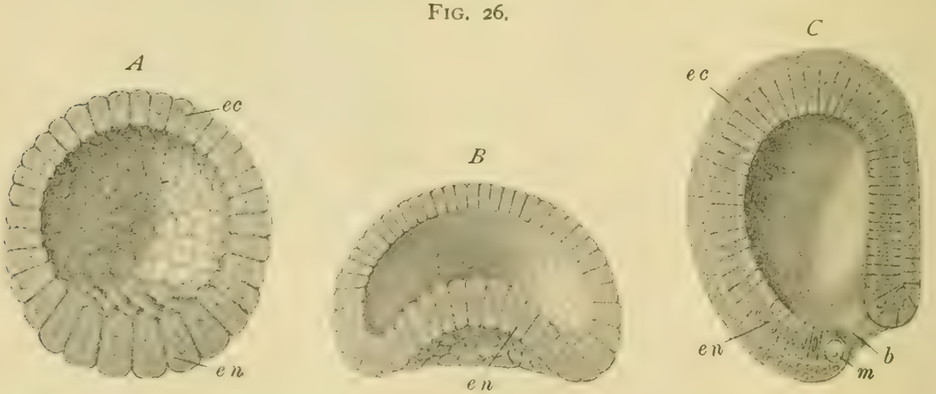
FIG. 25.



Transverse section through cephalic end of primitive streak of very young rabbit embryo. × 100.

The Neural Canal.—The earliest indication of the embryo consists in the appearance of two slightly diverging folds (Fig. 27), enclosing the anterior end of the primitive streak, which are produced by a local proliferation and thickening of the ectoblast. These are the *medullary folds* and mark the beginning of the formation of the *neural canal*, from which the great cerebro-spinal nervous axis, together with its outgrowths, the peripheral nerves, is derived. The medullary folds at first border a shallow and widely open furrow (Fig. 28), the *medullary groove*; the latter becomes rapidly deeper and narrower as the medullary folds increase in height and gradually approach each other. The approximation of the folds (Fig. 29) and subsequent fusion take place earliest at some distance behind the cephalic end of the groove, at a point which later corresponds to the upper cervical region of the spinal cord.

FIG. 26.



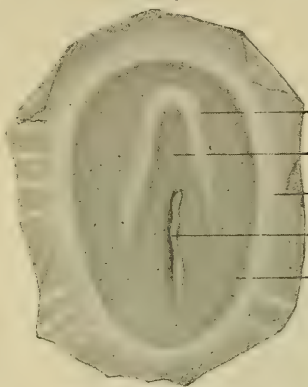
Blastula and gastrula stages in the development of amphioxus, drawn from the models of *Hatschek*. × 260. *A*, blastula composed of single layer of cells surrounding segmentation cavity; *ec*, *en*, respectively ectoblastic and entoblastic areas. *B*, beginning invagination of entoblastic area (*en*). *C*, completed gastrula; *ec*, *en*, ectoblast and entoblast; *m*, mesoblast cell; *b*, blastopore, leading into archenteron.

After the closure of the groove and its conversion into the medullary canal (Fig. 32), the thickened and invaginated ectoblast forming the lining of the neural tube becomes separated from the outer layer of the embryo by the ingrowth of the

mesoblast. The subsequent differentiation of the walls of the neural tube will be more fully considered in connection with the nervous system; suffice it here to state that the cephalic portion expands into the brain vesicles, and subsequently becomes the brain with the contained ventricles, while the remainder of the tube becomes the spinal cord, enclosing the minute central canal.

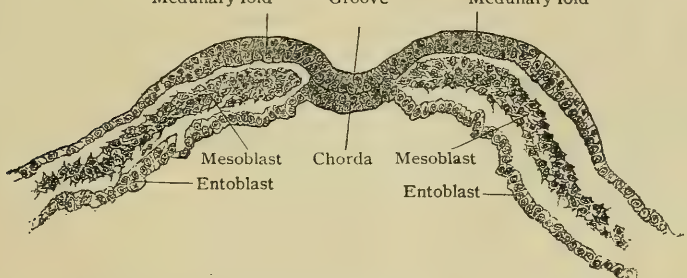
The Notochord.—Coincidently with the formation of the medullary groove the entoblast opposite the bottom of that furrow exhibits proliferation and thickening; the group of cells thus differentiated becomes separated from the general mass of the inner layer and takes up a position immediately below the neural tube (Figs. 30, 31). This isolated column of entoblastic cells constitute the *notochord*, or *chorda dorsalis*, the earliest suggestion of the cardinal vertebrate axis around which the parts of the early embryo are symmetrically arranged. While for a time constituting the sole longitudinal axis of the embryo, extending from a point near the cephalic pole, which corresponds later

FIG. 27.



Embryonic area of rabbit of about eight and one-half days, seen from the surface. × 24. (*Kollmann.*)

FIG. 28.



Transverse section of rabbit embryo of about eight and one-half days. × 80. Future neural canal is represented by widely open groove.

FIG. 29.

Transverse section of rabbit embryo of about nine and one-quarter days. × 80. Neural canal is just closing.

to the base of the skull, to the caudal extremity, the notochord is but a temporary structure, and subsequently is supplanted by the true vertebral column. It is

interesting to note, that in the connecting link between the vertebrates and invertebrates, the amphioxus, the notochord remains as the permanent and sole spinal axis.

The history of the notochord in man and mammals presents three stages : (*a*) it exists as an unbroken cord which extends uninterruptedly through the series of cartilaginous vertebræ ; (*b*) the notochord suffers segmentation in such manner that the breaks in its continuity correspond to the vertebral bodies, conspicuous proliferation and local increase in its substance, on the contrary, marking the

FIG. 30.

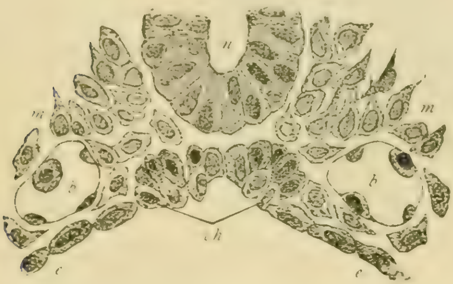


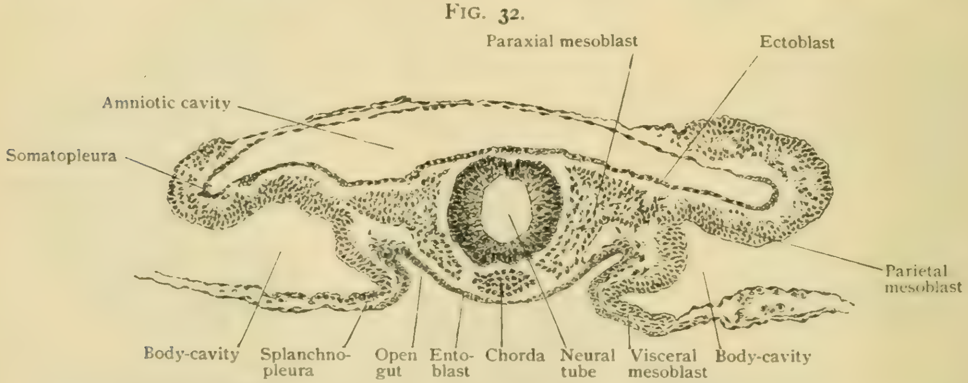
FIG. 31.

Transverse sections through axis of early human embryo of about fifteen days, showing formation of notochord from entoblast. High magnification. (*After Kollmann.*) *n*, neural canal; *ch*, cells forming notochord differentiating from entoblast (*e*); *m*, mesoblast; *s*, early somite; *b*, sections of primitive aortæ.

position of the intervertebral disks in which the chordal tissue during the first months after birth is represented by a considerable mass of central spongy substance ; (*c*) atrophy of the remains of the notochord, resulting in the entire disappearance of the chordal tissue within the vertebræ and the reduction of the proliferated intervertebral cell-mass to the pulpy substance existing within the intervertebral disks.

The cephalic end of the notochord in man corresponds in position to the dorsum sellæ, and marks the division of the skull into two parts, that lying in front of

FIG. 32.



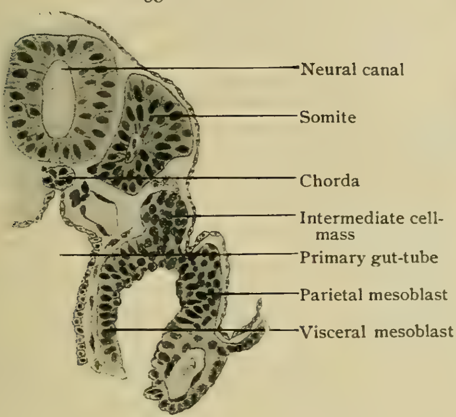
Transverse section of rabbit embryo of about nine and one-quarter days. × 80. Neural canal is now closed.

the termination of the notochord, the *prechordal portion*, and that containing the notochord, the *chordal portion ;* the latter is sometimes described as the vertebral segment of the skull.

The Cœlom.—The downward growth of the neural ectoblast and the upward extension of the chordal entoblast effect a division of the mesoblast along the embryonic axis into two sheets (Fig. 28). These latter undergo further division in consequence of the formation of a cleft within their substance, as the result of which the mesoblast becomes split into two layers enclosing a space, the *cœlom*, or *primary body-cavity* (Fig. 29).

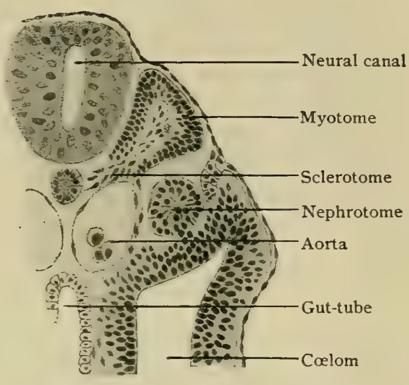
The cleavage of the mesoblast, however, does not extend as far as the mid-line of the embryo, but ceases at some distance on either hand, thus leaving a tract of uncleft mesoblast on either side of the medullary groove and the chorda. The uncleft area constitutes the *paraxial mesoblast* (Fig. 32), which extends from the head towards the caudal pole and appears upon the dorsal surface of the embryo as two distinct ribbon-like tracts bordering the neural canal. Beyond the paraxial mesoblast, the cleft portions of the middle layer extend on either side as the *lateral plates;* each lateral plate consists of two laminæ, the one forming the dorsal and the

FIG. 33.



Transverse section of human embryo of about fifteen days, showing early differentiation of somite. × 210. (*Kollmann.*)

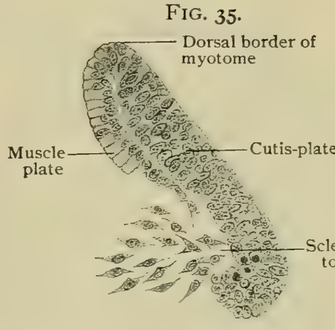
FIG. 34.



Transverse section of human embryo of about twenty-one days, showing differentiation of somite. × 90. (*Kollmann.*)

other the ventral boundary of the enclosed primary body-cavity; in view of their subsequent relations to the formation of the body-walls and the digestive tube respectively, the dorsal mesoblastic lamina is appropriately named the *parietal layer* and the ventral lamina the *visceral layer* (Fig. 32). In the separation of these layers, which soon takes place in consequence of the dorsal and ventral folding occurring during the formation of the amnion and the gut-tube, the parietal mesoderm adheres to the ectoblast, in conjunction with which it constitutes the *somatopleura* (Fig. 29), the ecto-mesoblastic sheet of great importance in the production of the lateral and ventral body-walls. Similarly, the visceral mesoblast unites with the entoblast to form the *splanchnopleura* (Fig. 29), the ento-mesoblastic layer from which the walls of the primary digestive canal are formed.

FIG. 35.



Differentiation of myotome of human embryo of about twenty-one days. × 525. (*Kollmann.*)

The Somites.—The paraxial mesoblast at an early stage—about the twentieth day in man—exhibits indications of transverse division, in consequence of which this band-like area becomes differentiated into a series of small quadrilateral masses, the *somites*, or *protovertebræ*. This segmentation of the embryonic mass appears earliest at some distance behind the cephalic end of the embryo, at a point which later corresponds to the beginning of the cervical region. The somites are seen to best advantage in the human embryo at about the twenty-eighth day (Fig. 71).

The early somites, on transverse section, appear as irregular quadrilateral bodies, composed of mesoblast and covered externally by ectoblast, lying on either side of the neural canal and the notochord (Fig. 33). Each somite consists of a dorsomesial *principal cell-mass*, which is connected with the lateral plate by means of an intervening cell-aggregation, the *intermediate cell-mass* (Fig. 33). Subsequently,

the latter becomes separated from the remaining portion of the somite and is probably identified with the formation of the segmented excretory apparatus of the embryo, the Wolffian body, and hence is known as the *nephrotome*.

The *principal mass*, including the greater part of the somite proper, consists of an outer or peripheral zone of condensed mesoblast enclosing a core of looser structure. The less dense mesoblastic tissue later breaks through the surrounding zone on the side directed towards the notochord and forms a fan-shaped mass of embryonic connective tissue which envelops the chorda and grows around the neural canal. The cell-mass derived from the core of the myotome constitutes the *sclerotome*, and directly contributes the tissue from which the permanent vertebræ and the associated ligamentous and cartilaginous structures arise. The remaining denser part, the *myotome*, which collectively forms a compressed C-like mass, becomes differentiated into a lateral and a mesial stratum (Fig. 35). The lateral stratum, sometimes called the *cutis-plate*, consists of several layers of closely packed elements. By some these cells are regarded as concerned in producing the connective tissue portion of the skin; according to others they are in large part converted into *myoblasts*, which, with those of the mesial stratum, or *muscle-plate*, give rise to the voluntary muscles of the trunk. The genetic relations of the somite, therefore, may be expressed as follows:

SOMITE . . . . { Myotome—*muscle segment.* / Sclerotome—*axial segment.* / Nephrotome—*excretory gland segment.* }

The number of somites of the human embryo is about thirty-seven, comprising eight *cervical*, twelve *thoracic*, five *lumbar*, five *sacral*, and from five to seven *caudal* segments.

THE FŒTAL MEMBRANES.

The Amnion.—With the exception of fishes and amphibians,—animals whose development takes place in water,—the young vertebrate embryo is early enveloped in a protecting membrane, the amnion. Animals possessing this structure, including reptiles, birds, and mammals, are classed, therefore, as *amniota*, in contrast to the *anamnia*, in which no such envelope is formed. An additional fœtal appendage, the *allantois*, is always developed as a structure complemental to the amnion; hence the amniota possess both amnion and allantois.

FIG. 36.

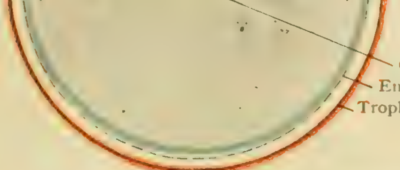


Diagram of mammalian blastodermic vesicle.

Since the development of the fœtal membranes in man presents certain deviations from the process as seen in other mammals, due to peculiarities affecting the early human embryo, it is desirable to examine briefly the formation of these structures as observed in animals less highly specialized.

Referring to the early mammalian embryo, in which the blastodermic layers are arranged as somatopleura and splanchnopleura on either side of the embryonic axis and the surrounding uncleft mesoderm, and extend as parallel sheets over the enlarging blastodermic vesicle, the first trace of the amnion appears as a duplicature of the somatopleura. The earliest indication of the process is seen slightly in front of the cephalic end of the embryo, the resulting *head-fold* being, however, soon followed by the appearance of the *lateral* and *tail-folds*. The rapid growth of these

duplicatures of somatopleura from all sides results in the encircling of the embryo within a wall which increases in height until the prominent edges of the folds meet and coalesce over the dorsal aspect of the enclosed embryo. The folds of the amnion first meet over the head-end, from which point the union extends tailward, where, however, fusion may be delayed for some time. The line along which the junction of the folds takes place is known as the *amniotic suture*.

The amnion thus forms a closed sac completely investing the embryo and containing a fluid, the *liquor amnii;* at first closely surrounding the embryo, the amniotic sac rapidly expands until its dimensions allow the enclosed fœtus to turn freely, practically supported by the amniotic fluid, which possesses a specific gravity of 1003. It has long been known that in certain forms, conspicuously in the chick, the amnion executes rhythmical contractions, at the rate of ten per minute, whereby the embryo is swayed from end to end of the sac. From the manner of its formation, as folds of the somatopleura (Figs. 37 and 38), it is evident that the amnion consists of an inner ectoblastic and an outer mesoblastic layer.

FIG. 37.

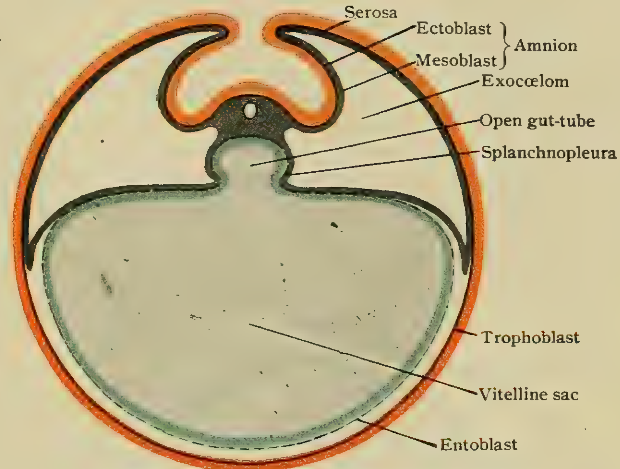


Diagram showing formation of amniotic folds and of gut-tube; transverse section of axis of embryo.

The Serosa, or False Amnion.—Coincident with the fusion of the inner layers of the somatopleuric folds to form the closed sac of the amnion, the outer layers of the same folds unite to produce a second external envelope, the *serosa*, or *false amnion*. The serosa soon becomes separated from the amnion by an intervening space to form the *primitive chorion;* the latter, therefore, consists of ectoblast externally and mesoblast internally, the reverse of the disposition of these layers in the amnion.

FIG. 38.

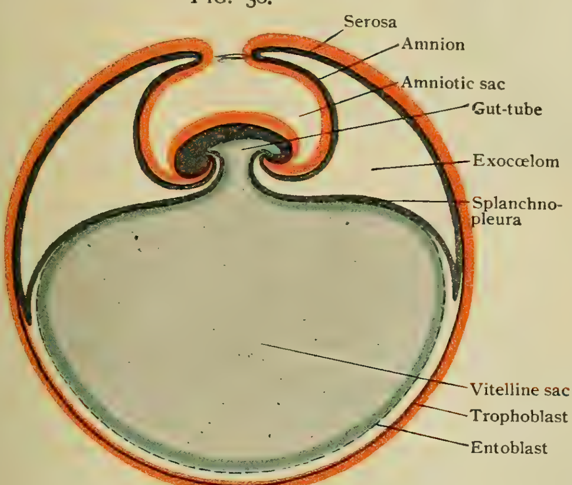


Diagram showing formation of amniotic folds and vitelline sac; longitudinal section of embryo.

The outer surface of the mammalian primitive chorion—the entire envelope formed of the serosa and the trophoblast—is distinguished by proliferation of the epithelial elements, which process results in the production of more or less conspicuous projections or *villi* (Fig. 40), this villous condition being particularly well marked in man.

The ectoblast of the primitive chorion takes no part in the formation of the body of the embryo, but, on the other hand, assumes an important rôle in establishing the earliest connection between the embryo and the maternal tissues and, later, participates in the formation of the placenta. The ectoblast of the

primitive chorion is the direct derivative of the original ectodermal layer of the blastodermic vesicle beyond the embryonic region proper, a layer which, on account of this important nutritive function, has been called by Hubrecht the *trophoblast.*

As already noted (Fig. 32), the cleft between the parietal and visceral layers of the mesoblast is the primary body-cavity or cœlom ; with the separation of these layers following the dorsal and the ventral folding associated respectively with the formation of the amniotic sac and the gut-tube, the intramesoblastic space becomes greatly expanded and extends between the amnion and primitive chorion. This large space is appropriated only to a limited extent by the future definite body-cavity, and hence is divisible into an embryonic and an extra-embryonic portion, or *exocœlom* (Fig. 38), which are temporarily continuous.

The Vitelline Sac.—While the somatopleura is engaged in producing the protecting amniotic sac, the splanchnopleura, composed of the entoblast and the adherent visceral layer of mesoblast, becomes approximated along the ventral surface of the embryo to define the primitive gut-tube by enclosing a part of the blastodermic vesicle ; the remaining, and far larger, portion of the latter cavity constitutes the *vitelline sac,* and corresponds to the yolk-sac of the lower forms.

The constriction and separation of the gut-tube from the vitelline sac is accomplished earliest at the cephalic and caudal ends of the future alimentary canal, the intervening portion remaining for a time in widely open communication with the yolk-sac. During the rapid diminution of the latter the communication becomes reduced to a narrow channel, the *vitelline duct,* which persists as a slender stalk terminating at its distal end in the remains of the yolk-sac.

FIG. 39.

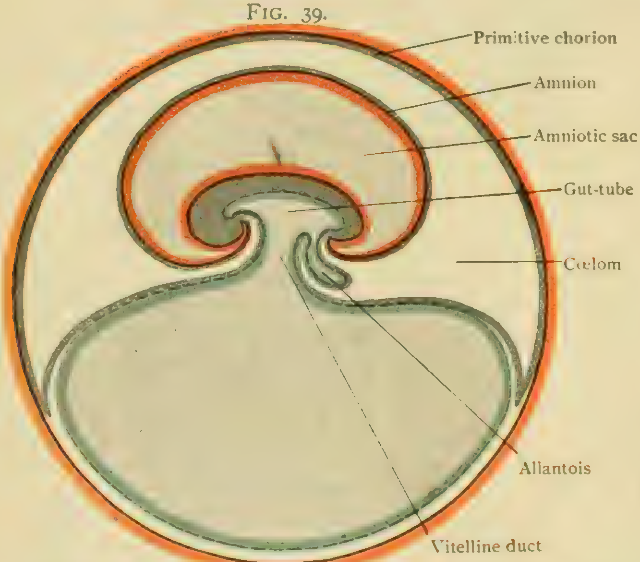


Diagram showing completed amnion and serosa, beginning allantois and vitelline duct.

In animals other than mammals in which a placenta is developed, the yolk-sac is the chief nutritive organ of the embryo ; the mesoblastic tissue of the vesicle becomes vascularized by the development of the blood-vessels constituting the vitelline circulation, of which the *vitelline* or *omphalomesenteric* arteries and veins form the main trunks. The contents of the yolk-sac as such do not directly minister to the nutrition of the embryo, but only as materials absorbed by the vitelline blood-vessels. In man and other high mammals the nutritive function of the yolk is at best insignificant, the vitelline sac of these animals representing the more important organ of their humbler ancestors. In the lowest members of the mammalian group, the monotremata, in which the large ova are comparatively rich in deutoplasm, the vitelline circulation is of great importance for nutrition, since it constitutes the sole means for this function until the immature animals are hatched and supplied with milk by the mother. In the kangaroo and opossum the yolk-sac at one point forms a disk-like organ, which, from the fact that it becomes provided with vascular villi that lie in contact with the uterine mucous membrane, is termed the *vitelline placenta.*

The Allantois and the Chorion.—Coincidently with the formation of the amnion, another fœtal appendage, the *allantois,* makes its appearance as an out-

growth from the caudal segment of the primary gut-tract. Although modified in man and certain mammals to such an extent that its typical form and relations are obscured, the allantois, when developed in a characteristic manner, as in the chick, assumes the appearance of a free vesicle connected with the embryo near its caudal pole by means of a narrow pedicle, the *allantoic stalk*. Since the allantois is an evagination from the primitive gut, its walls are formed by direct continuations of the primary layers enclosing the digestive canal,—namely, a lining of entoblastic cells, reinforced externally by a layer of visceral mesoblast.

Beginning as a wide bay on the ventral wall of the hind-gut, the allantois elongates and appears as a pyriform sac projecting from the embryo behind the attachment of the still large vitelline stalk (Fig. 39). It rapidly grows into the exocœlom, and in mammals expands in all directions until it comes into contact with the inner surface of the primitive chorion, with which it fuses to constitute the true *chorion*. The latter, sometimes spoken of as the *allantoic chorion* in contrast to the amniotic or primitive chorion, now becomes the most important envelope of the mammalian embryo on account of the rôle that it is destined to play in establishing the respira-

FIG. 40.

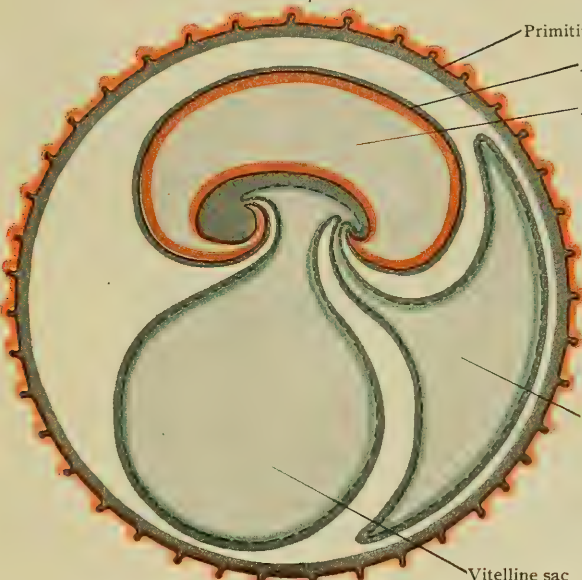


Diagram showing villous condition of serosa, expanding allantois, and diminishing vitelline sac.

tory and nutritive organ of the fœtus, the placenta. After the fusion of the allantois with the primitive chorion to form the chorion, the villous projections upon the external surface of the latter become more highly developed, consisting of a core of mesoblastic tissue covered externally by the ectoblast.

The primary purpose of the allantois, as a receptacle for the effete materials excreted by the Wolffian body of the early fœtus, is soon overshadowed by its function as a respiratory organ ; this occurs with the appearance of the rich vascular supply within the chorion following the invasion of its mesoblastic tissue by the blood-vessels constituting the allantoic circulation. The latter includes the two *allantoic arteries*, which are extensions from the aortic stem of the embryo and convey venous blood, and the two *allantoic veins*, which return the oxygenated blood to the embryo and become tributary to the great venous segment of the primitive heart. The vascularization of the chorion extends to the highly developed villi occupying its outer surface in many mammalian forms, especially man.

The vascular *villi of the chorion*, bearing the terminal loops of the blood-vessels conveying the fœtal blood, are important structures on account of their intimate relations with the uterine mucous membrane (Fig. 41), in conjunction with which

they form a respirative and nutritive apparatus. The intimacy between the uterine mucous membrane and the chorionic tufts presents all degrees of association, from simple apposition, as seen in the sow, where the feebly developed and almost uniformly distributed vascular projections are received within corresponding depressions in the richly vascular uterine tissue, to the firm and complex attachment found in the highly developed human placenta.

FIG. 41.

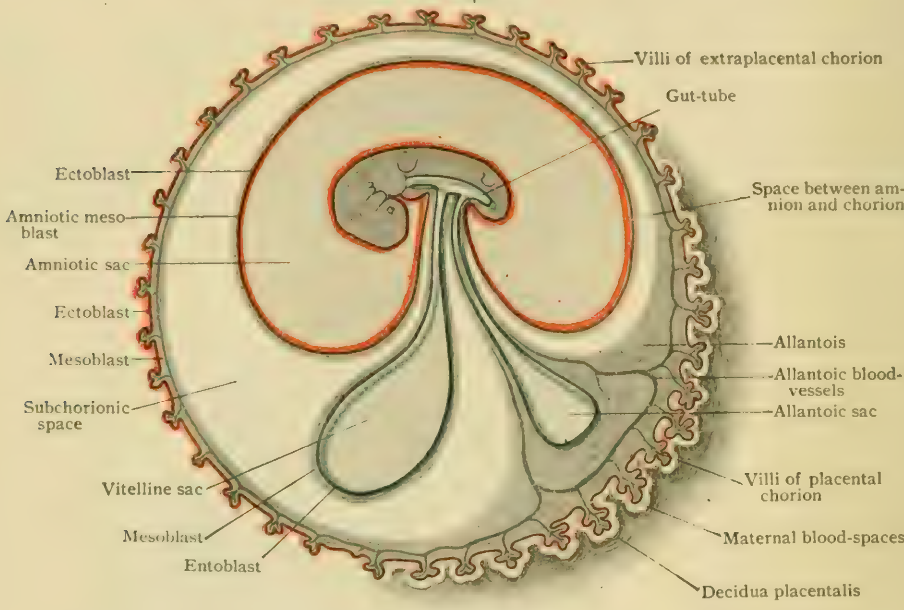
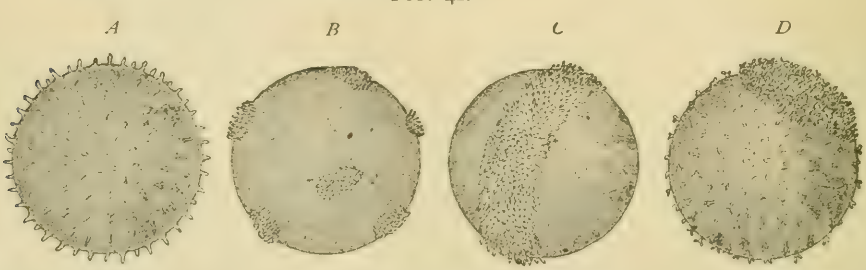


Diagram showing villous chorion, differentiation of placental area, and vascularization of chorion.

In contrast with the chorion of those animals in which the nutritive relations between the maternal tissues and the embryo are uniformly distributed are the local specializations seen in the chorion of those types in which a placental area is developed. The animals in which the latter condition obtains are known as *placentalia*, of which three subgroups are recognized depending upon the *multiple* (cotyledons),

FIG. 42.



Diagrams illustrating the various types of development of the chorion. *A*, uniformly developed villi (hog, horse); *B*, multiple placentæ or cotyledons (cow, sheep); *C*, zonular placenta (cat, dog); *D*, discoidal placenta (monkey, man). *A–B* comprise non-deciduate; *C–D*, deciduate mammals.

zonular, or *discoidal* form of the placenta, man and the apes representing the highest specialization of the last division. In its general plan of development, therefore, the placenta is formed of a *fœtal* and a *maternal* portion, the former consisting of the vascular villi which are unusually well developed within a particular portion of the chorion, and the latter of the opposed uterine lining which becomes highly specialized throughout a corresponding area and more or less intimately united with the

fœtal structures. The mucous membrane of the entire uterine cavity, in many of the higher mammals, suffers profound change, and before the end of gestation becomes inseparably attached to the chorion even in its extent beyond the placental area ; in such animals the fused uterine and chorionic tissue constitute the *deciduæ* which, lined internally by the closely applied amnion, form the membranous envelope enclosing the fœtus. After rupture consequent upon the expulsion of the fœtus at the termination of pregnancy, the deciduæ, including the specialized placental portion, are separated from the uterine wall and expelled as the *membranes* and the *placenta* which are known collectively as the *after-birth.*

The foregoing sketch of the general development of the fœtal membranes in the higher mammals must be now supplemented by consideration of the peculiarities encountered in the development of these structures in man.

THE HUMAN FŒTAL MEMBRANES.

The young human embryo is distinguished by the very early formation of the amniotic cavity, by the precocious development of the mesoblast and extra-embryonic cœlom, by the presence of the body-stalk and by the great thickening of the trophoblast. It must be remembered, in considering the formation of the human fœtal membranes, that the earliest stages of development, to wit, fertilization, segmentation, the formation of the blastodermic vesicle, the earliest differentiation of the embryonic area and the formation of the amniotic cavity have not yet been observed on human specimens. Our knowledge of these processes is derived from a study of some of the lower types ; beyond these very early stages, however, the conditions in the human embryo have been subject to direct study.

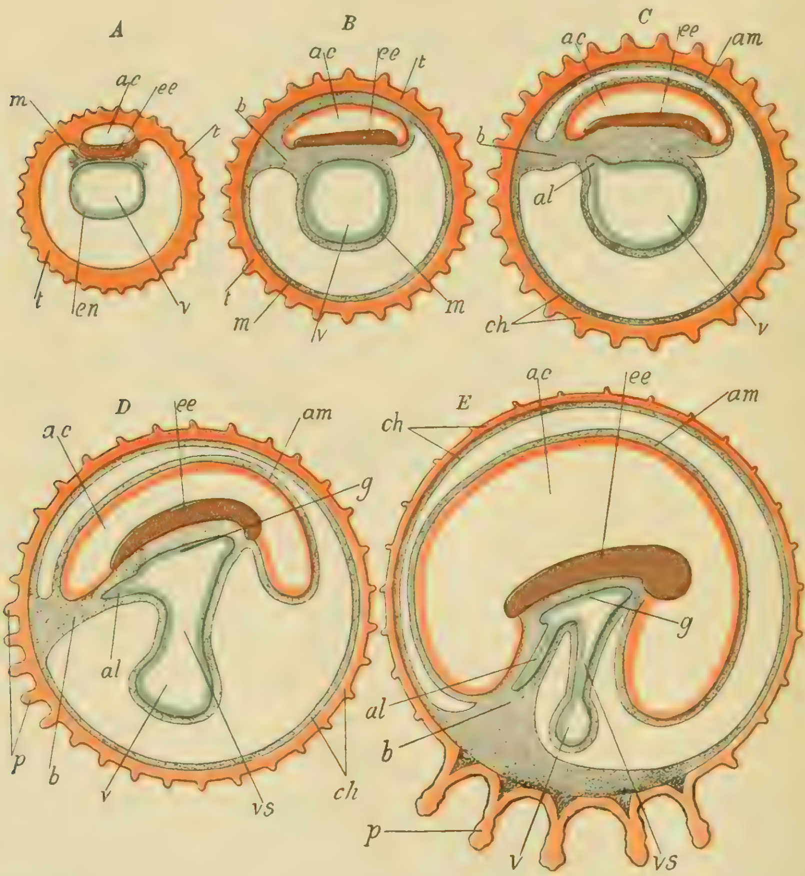
The Human Amnion, Amniotic Cavity and Allantois.—The accompanying diagrams (Fig. 43) will serve to illustrate the process of formation of the fœtal membranes in man. Of these five diagrams, *A* alone is purely hypothetical with reference to the human embryo. In diagram *A* the amniotic cavity is already indicated as a small cleft between the embryonic area below and a covering layer of cells above continuous with the trophoblast. This layer, the *trophoblast*, forms the outer covering of the entire vesicle. It is presumably already thickened at as early a stage as this diagram represents. Presumably also the surface of the trophoblast shows irregularities, for this tissue it is which comes into direct contact with the uterine mucous membrane and which, by its activities, forces its way into the maternal decidua. This latter process is known as *implantation*, a process which supposedly is taking place, if not completed, at about the stage of this diagram. Whether the trophoblastic layer in man is originally a thin single sheet of cells, as for instance is the case in the rabbit, or whether it is from the beginning thickened, we do not know. Certainly the thickened condition appears at a very early stage. The embryonic area shows the embryonic ectoblast proper, which is of small extent ; this ectoblast being so distinguished from the trophoblastic ectoblast. The entoblast beneath is represented as already arranged in the form of a sac. Between the entoblast and ectoblast the mesoblast has made its appearance. It will be noted that in the diagram the entoblastic sac is much smaller than the outer trophoblastic vesicle. We do not know that this is really the condition when the entoblastic sac is first formed or only appears in conjunction with the great development of the extra embryonic cœlom in the mesoblast. It is certainly not unreasonable to suppose that the former case is the true one.

The early appearance of the amniotic cavity is to be explained in this way. After the blastodermic vesicle has reached the stage when the inner cell mass is attached to one point on the inner surface of the trophoblast, the formation of a cavity occurs in the region of the inner mass. This cavity, at first very small, has below it the cells of the inner mass, which soon become arranged into the two primary germ layers of the embryonic area, ectoblast and entoblast, while above the cavity is a layer of cells continuous with the trophoblast. Such a method of formation of the amniotic cavity has been observed in some of the lower forms, for instance, in a lemur by Hubrecht, and since the earliest human embryo accurately studied shows a completely closed amniotic cavity, while in

a very early stage of development it is a reasonable inference that in man such a process actually occurs.

In diagram *B* the mesoblast has not only surrounded the entoblastic sac and the inner surface of the trophoblast, so enclosing the large extra-embryonic cœlom, but has invaded the layer of cells above the amniotic cavity, dividing this layer into two parts, the inner part going to form the ectoblast of the amnion, the outer part being a continuation of the trophoblast of the chorion There is here evidently a very great development of the extra-embryonic cœlom. In explanation of this condition, it may be assumed that the entoblastic sac is at first much smaller than the trophoblastic covering of the vesicle ; that the mesoblast, shortly after its appearance,

FIG. 43.



Diagrams illustrating development of human fœtal membranes. Stage *A* is hypothetical ; others are based on stages which have been actually observed. Red represents trophoblast ; purple, embryonic ectoblast ; gray, mesoblast ; blue, entoblast. *ac*, amniotic cavity ; *al*, allantois ; *am*, amnion ; *b*, body-stalk ; *ch*, chorion ; *ee*, embryonic ectoblast ; *en*, entoblast ; *g*, gut-tube ; *m*, mesoblast ; *p*, placental area ; *t*, trophoblast ; *v*, yolk-sac ; *vs*, yolk-stalk.

develops a cœlom ; that the two layers of the mesoblast so formed grow separately around the vesicle ; the splanchnic layer around the entoblast, the somatic layer around the trophoblast, so enclosing between them as they grow, the considerable space which becomes, by this process, extra-embryonic body cavity. This diagram corresponds roughly to the condition of Peters' embryo (Fig. 44). The trophoblast is greatly thickened ; its outer surface very irregular, showing lacunæ or spaces filled with maternal blood. This early intimate contact of the fœtal tissue with the maternal blood permits nutrition of the young embryo from the maternal blood to be carried on through the trophoblast cells some time before the allantoic circulation and definite placenta are established. Hence the significance of this term trophoblast.

In the next diagram, (Fig. 43), *C*, the extra-embryonic cœlom has invaded the sheet of mesoblast above the amniotic cavity to such an extent that the chorion is completely separated from the amnion and the body of the embryo except at one point, the posterior end of the body, where a solid stalk of mesoblast connects the chorion and embryo. This solid band of mesoblast is called the *body-stalk*. It represents, therefore, a primary and permanent connection between the chorion and the body of the embryo. A small diverticulum from the entoblastic sac growing into the mesoblast of the body-stalk marks the beginning of the *allantois*. As the diagram shows, the amnion is at first a comparatively small membrane overlying the embryonic area. The ectoblast of the amnion is on the inner side facing the embryo, the mesoblast on the outer side. In the chorion these layers are placed inversely, the mesoblast on the inner side, the ectoblast (trophoblast) outside. The space between amnion and chorion is seen to be a continuation of the extra-embryonic cœlom.

In diagram *D*, the amnion has become considerably expanded in association with the growth of the body of the embryo and the accumulation of amniotic fluid. A constriction in the entoblastic sac has made its appearance, a constriction which separates the gut of the embryonic body from its appendage, the yolk-sac, the narrower connecting piece being known as the *yolk-stalk*, or sometimes as the *vitello-intestinal duct*. This constricted area is brought about by the rapid growth of the body of the embryo. In the early condition the entoblastic sac is attached to the embryonic body practically along its entire ventral surface. The body region grows very rapidly, particularly the head end, which comes to project from the entoblastic sac to a marked extent; the tail end also projects somewhat. There is a corresponding growth of the gut within the body of the embryo. As a consequence of this process of expansion of the body, the area of attachment of the entoblast external to the body becomes relatively much reduced in size, occupying only a small portion of the ventral surface of the body, and a progressively smaller portion as the body increases in bulk. In other words, the narrow area of the yolk-stalk makes its appearance.

In the diagram (*D*, *al*) the allantois projects from the posterior end of the embryonic gut into the body-stalk. It will be noticed that the human allantois is never a free structure as it is in many of the lower types, where it grows from the body freely into the extra-embryonic cœlom and only later becomes connected with the chorion to form the placenta, but that in man it grows directly into the body-stalk, where, outside of the body of the embryo, it is an insignificant structure. Inside the body, part of the allantois persists as the bladder. The urachus, a fibrous cord which in the adult passes from the top of the bladder to the umbilicus, is also a remnant of the allantois. The thick irregular projections of the trophoblast have received a core of mesoblast tissue, so forming the early chorionic villi. These villi, at the point of attachment of the body-stalk, the area where the placenta is developing, are increasing in size, while the villi over the remainder of the chorion are diminishing in size.

In diagram *E*, the amnion has become greatly expanded. It lies closer to the inner surface of the chorion. In close association with this expansion of the amnion, and the accompanying growth of the body of the embryo, the structures which form the umbilical cord are so closely approximated that the area of the cord is clearly defined. These structures are the body-stalk containing the allantois and allantoic vessels, the yolk-stalk, and, bounding the other side of this area, the fold of the amnion from beneath the head. At first the body-stalk projects from beneath the extreme posterior end of the body of the embryo, but as growth in this part of the body advances and the tail projects more and more, the body-stalk is brought to the ventral surface of the abdominal region in close proximity to the yolk-stalk. The allantoic blood-vessels grow from the embryo through the body-stalk to the chorion, where they ramify in the chorionic villi. At first there is an extension of the cœlom about the yolk-stalk in the umbilical cord, but the mesoblast tissues of the structures of the cord soon fuse together, obliterating this cavity. The area of attachment to the abdomen of the umbilical cord becomes relatively very much reduced in size and is known in the adult, after the separation of the cord, as the *umbilicus* or *navel*.

The chorionic villi at the point of attachment to the chorion of the body-stalk are enlarged. These villi constitute the fœtal portion of the placenta, the so-called *chorion frondosum*. They are imbedded in the maternal decidua, more specifically, the *decidua basalis* or *placentalis*. It must be remembered that the villi contain a core of mesoblast tissue in the stage represented by diagram *E*, although this mesoblastic core is not shown in the figure, and that the allantoic blood-vessels run in

FIG. 44.

Section of mucous membrane, decidua, of a pregnant uterus containing imbedded in it an extremely young human embryonic vesicle, described by Peters. *a*, *b*, points of entrance of embryonic vesicle; *B. L.*, blood lacunæ; *B. Z.*, Bordering zone; *Ca.*, capillary in uterine tissue; *Cap.*, beginning of decidua capsularis; *Comp.*, compact tissue of uterine mucosa; *E.*, embryo; *g.*, gland of uterus; *M.*, mesoblast; *Sy.*, syncytium; *T. M.*, covering tissue over break in uterine surface; *Tr.*, trophoblast; *U. E.*, epithelium of uterine mucosa. × 50 (*Peters*).

this mesoblast: also that the villi are in reality considerably branched, not straight as in the diagram. The remainder of the chorion is acquiring a smooth surface and is commonly known as the *chorion læve*, as a means of distinguishing the extra-placental portion of this membrane. The yolk-sac, in man called the *umbilical vesicle*, at the extremity of the yolk-stalk, is retained usually in the placental area just beneath the amnion. It is possible to find the yolk-sac in nearly every placenta

by slightly stretching the umbilical cord at its insertion, when a fold appears containing no large vessels. This fold points to the position of the yolk-sac.

To sum up, the chief peculiarities of the human fœtal membranes are the following:

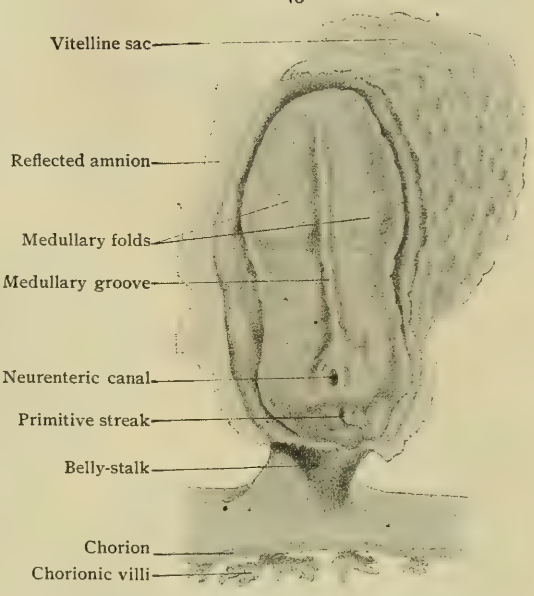
1. The amniotic cavity is developed at a very early period apparently by a process of hollowing out in the region of the cells of the inner mass, and not by any folding process. The cells above this primitive amniotic cavity are later split into two portions by the entrance of the mesoblast and extra-embryonic cœlom; the inner portion becomes the ectoblast of the amnion, the outer portion is merely a part of the the trophoblast of the chorion.

2. The mesoblast and extra-embryonic cœlom are precociously developed at a very early period.

3. The body-stalk constitutes a primary and permanent connection between the embryo and the chorion.

4. The allantois, which, external to the body of the embryo, is an insignificant structure, grows into the body-stalk and therefore is never a free vesicle.

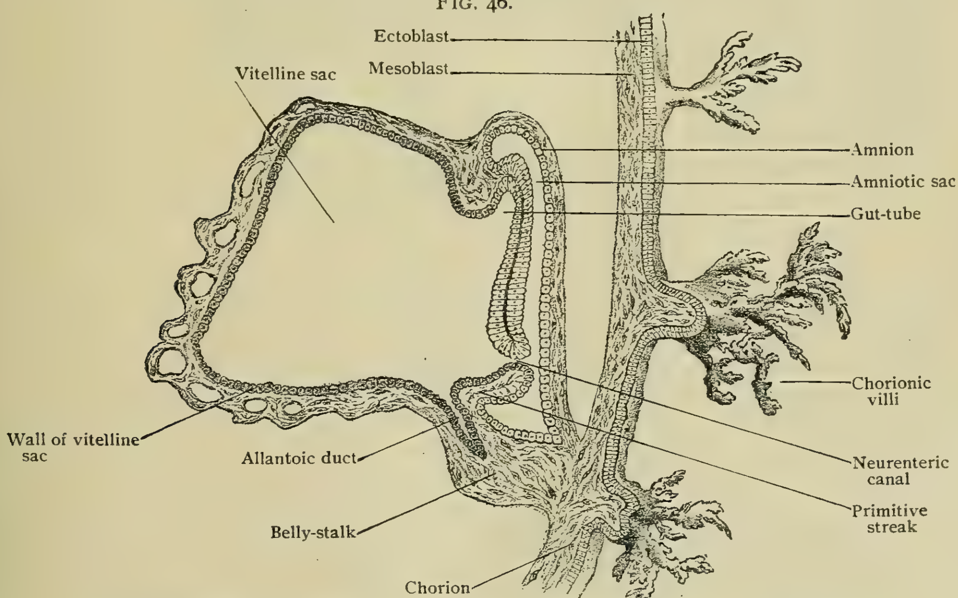
FIG. 45.



Dorsal surface of early human embryo, two millimetres in length. × 23. (*After Spee.*) The amnion has been divided and turned aside.

5. The trophoblast is very early greatly proliferated and very early in intimate contact with the maternal blood.

FIG. 46.

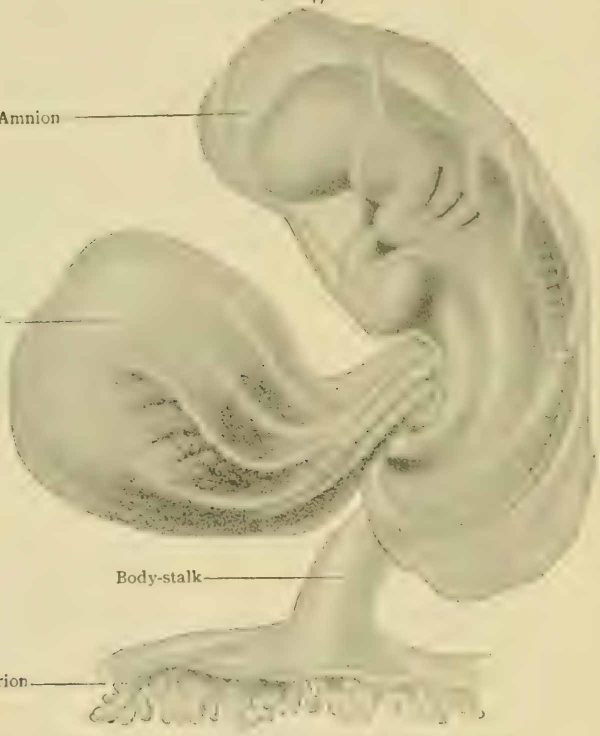


Longitudinal section of human embryo represented in preceding figure. × 23. (*After Spee.*)

Fig. 44, page 38, is a reproduction of the drawing of Peter's embryo and deserves special attention. The figure shows a small portion of the mucous membrane of the uterus in which is imbedded the embryonic or chorionic vesicle.

Between the points *a*, *b* in the figure lies the area through which the embryonic growth has made its way into the mucous membrane of the uterus, and, in consequence, the uterine epithelium in this area has disappeared. Above this small area there lies a covering mass of tissue (*T. M.*) mainly composed of blood, the result evidently of hemorrhage following the breaking of the mucosa of the uterus in this region. The chorionic vesicle as a whole is quite large, especially in proportion to the embryonic area *E*, the surface of which is covered with a distinct columnar epithelium. Surrounding the chorionic vesicle there are two kinds of tissue, which make a very striking feature of the picture. First, there is the thickened and very irregular trophoblast, the cells of which appear dark, and which forms the outer covering of the wall of the embryonic vesicle itself. Then there are numerous large blood-spaces or

FIG. 47.



Human embryo of about twenty days, enclosed within the amnion. × 30.

blood-lacunæ lying among the irregular projections of the trophoblast. The maternal blood, therefore, in this very early condition bathes the trophoblast cells of the embryo, a relation very significant with reference to the nutrition of the embryo before the allantoic-placental circulation is established. The mesoderm (*M*) extends around the vesicle on the inner side of the trophoblast. In several places there are outgrowths of the mesoderm into the trophoblast, so indicating the beginnings of the villi of the chorion. It will be remembered that the cells of the trophoblast form the epithelial covering of the chorion. At several places in the figure the syncytial layer of the trophoblast *Sy* can be distinguished. The proportionally large cavity within the vesicle is extra-embryonic cœlom, a fact which can readily be verified by observing the relations of the mesoderm. The latter layer of tissue is seen to extend around the small yolk sac as the visceral layer of the mesoderm, while the layer of the mesoderm on the inner side of the trophoblast is of course the parietal layer, hence the cavity within these respective layers is the extra-embryonic cœlom, precociously developed for this early stage. There is a small amniotic cavity above the embryo. Between this cavity and the trophoblast the mesoderm extends as a solid sheet.

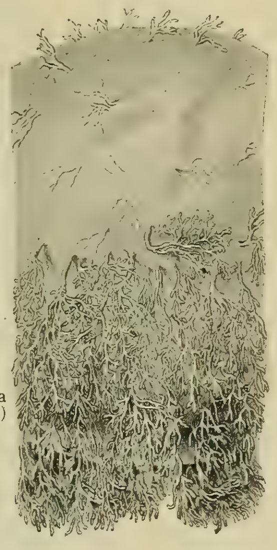
There are one or two more points to be noted in the figure. In the areas

marked *B. Z.*, which are merely portions of the uterine mucosa lying against the trophoblast, the tissue is oedematous in character. This tissue is described by Peters as the bordering zone. In other portions of the mucous membrane there are seen parts of some of the uterine glands (*g*). In the region marked *Cap.*, is seen the beginning of the decidua capsularis, growing in over the area through which the embryonic vesicle broke into the surface of the uterus. This layer, decidua capsularis, is at this stage scarcely developed, only the beginning of it is apparent.

This embryo, described by Peters, is one of the youngest which has been accurately studied. The inner dimensions of the vesicle, as given by Peters, are as follows: 1.6 by 0.8 by 0.9 mm. The youngest human embryo is that described by Bryce and Teacher, and is probably several days earlier than the one recorded by Peters. In a general way, it presents the relations of the amniotic and vitelline sacs already described.

The Human Chorion.—The vascular chorionic villi, although becoming more complex by the addition of secondary branches, are for a time equally well developed over the external surface of the entire embryonic vesicle; subsequently, from the end of the second month, a noticeable differentiation takes place, the villi included within the field that later corresponds to the placental area undergoing unusual growth and far outstripping those covering the remaining parts of the chorion. This inequality in the development of the villi led to the recognition of the *chorion frondosum* and the *chorion læve*, as the placental and non-placental portions of the chorion respectively are termed (Fig. 48). The vascular supply of the villi also shares in this differentiation, the vessels to those of the placental area becoming progressively more numerous, while, on the contrary, those distributed to the remaining villi gradually atrophy as the chorion comes into intimate apposition with the uterine tissue. When well developed, the chorionic villi possess a distinctive appearance, the terminal twigs of the richly branched projections being clubbed and slightly flattened in form. Their recognition in discharges from the vagina often affords valuable information as to the existence of pregnancy.

Fig. 48.



External surface of part of the human chorion of the third month; the lower portion is covered with the highly developed villi of the placental area.

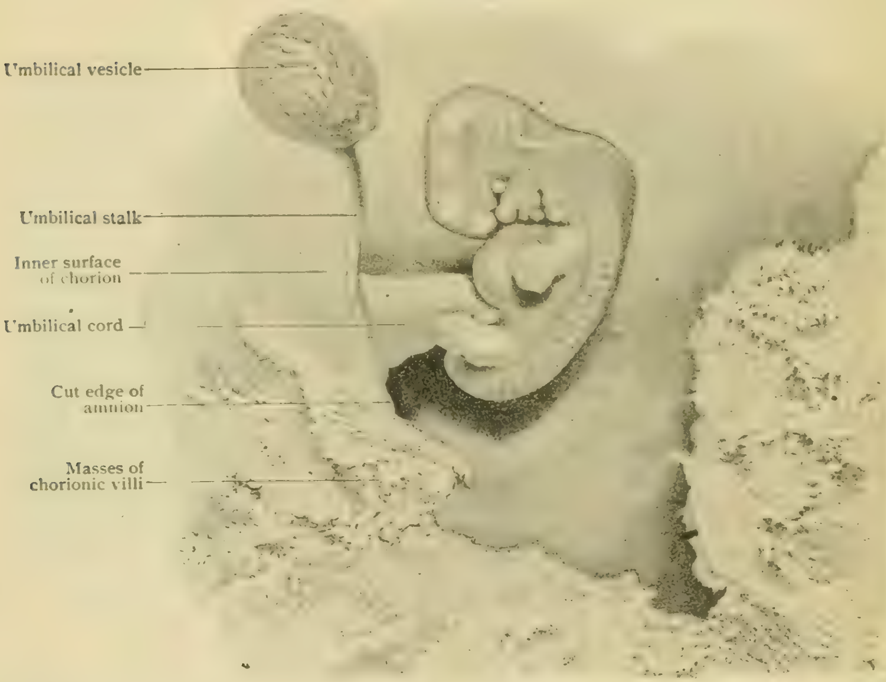
The Amniotic Fluid.—The amnion at first lies closely applied to the embryo, but soon becomes separated by the space which rapidly widens to accommodate the increasing volume of the contained *liquor amnii.* The accumulation of fluid within the amniotic sac, which in man takes place with greater rapidity than in other mammals, results in the obliteration of the cleft between the chorion and amnion until the latter envelope lies tightly pressed against the inner surface of the chorion. The union between the two envelopes, however, is never very intimate, as even after the expulsion of the membranes at birth the attenuated amnion may be stripped off from the chorion, although the latter is then inseparably fused with the remaining portions of the deciduæ.

The amniotic fluid, slightly alkaline in reaction, is composed almost entirely of water; of the one per cent. of solids found, albumin, urea, and grape-sugar are constituents. The quantity of liquor amnii is greatest during the sixth month of gestation, at which time it often reaches two litres. With the rapid increase in the general bulk of the fœtus during the later months of pregnancy, the available space for the amniotic fluid lessens, resulting in a necessary and marked decrease in the quantity of the liquid; at birth, less than one litre of amniotic fluid is usually present. Sometimes, however, the amount of the liquor amnii may reach ten

litres, due to pathological conditions of the fœtal envelopes; such excessive secretion constitutes *hydramnion*. During the later months of pregnancy the fœtus swallows the amniotic fluid, as shown by the presence of hairs, epithelial cells, etc., within the stomach. In view of the composition of the fluid, consisting almost entirely of water, it seems certain that the introduction of the liquor amnii does not serve the purposes of nutrition; on the other hand, it is probable, as held by Preyer, that the unusual demands of the fœtal tissues for water may be met largely in this manner.

The source of the amniotic fluid in man has been the subject of much discussion. While it has been impossible to determine accurately the extent to which the mother participates in the formation of this fluid, it may be accepted as established that the maternal tissues are the principal contributors; it is also probable that the fœtus likewise aids in the production of the liquor amnii; the latter, therefore, originates from a double source,—maternal and fœtal. The early amniotic fluid resembles

FIG. 49.



Human embryo of about thirty-three days. × 4. Amnion and chorion have been cut and turned aside.

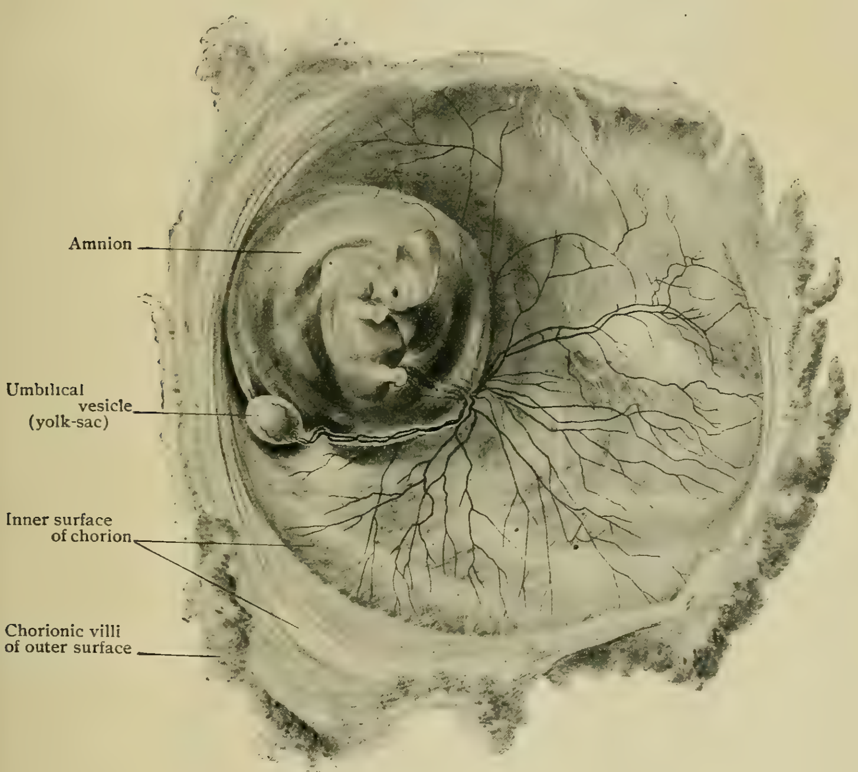
in appearance and chemical composition a serous exudate; later, after the formation of the urogenital openings, the liquor amnii becomes contaminated, as well as augmented, by the addition of the fluid derived from the excretory organs of the fœtus. During the later weeks of gestation the contents of the digestive tube are discharged into the amniotic sac as meconium.

The Umbilical Vesicle.—The umbilical vesicle, as the yolk-sac in man is termed, presents a reversed growth-ratio to the amnion and body-stalk since it progressively decreases as these latter appendages become more voluminous. The early human embryo is very imperfectly differentiated from the large and conspicuous yolk-sac, with which its ventral surface widely communicates. With the advances made during the third week in the formation of the primitive gut, the connection between the latter and the vitelline sac becomes more definitely outlined in consequence of the beginning constriction which indicates the first suggestion of the later vitelline or umbilical duct (Fig. 47). By the end of the fourth week the connection

between the umbilical sac and the embryo has become reduced to a contracted channel extending from the now rapidly closing ventral body-wall to the yolk-sac, which is still, however, of considerable size. The succeeding fifth (Fig. 50) and sixth weeks effect marked changes in the umbilical duct, now reduced to a narrow tube, which extends from the embryo to the chorion, where it ends in the greatly diminished vitelline sac. The lumen of the umbilical duct is conspicuous during the earliest months of gestation, but later disappears, the entoblastic epithelial lining remaining for a considerable time within the umbilical cord to mark the position of the former canal.

The chief factor in producing the elongation of the umbilical duct is the rapid expansion of the amnion ; with the increase in the amniotic sac the distance between this envelope and the embryo increases, until the amnion fills the entire space within

FIG. 50.



Chorionic sac of thirty-five day embryo laid open, showing embryo enclosed by amnion. ×2.

the chorion, against which it finally lies. In consequence of this expansion, the attachment between the embryo and the amnion around the ventral opening, which later corresponds to the umbilicus, becomes greatly elongated and narrowed. At this point the tissues of the embryonic body-wall and the amniotic layers are directly continuous. The tubular sheath of amnion thus formed encloses the tissue and structures which extend between the embryo and the chorion, as the constituents of the belly-stalk, together with the umbilical duct and the remains of the vitelline blood-vessels ; the delicate mesoblastic layer of the amnion fuses with the similar tissue of the allantois, the whole elongated pedicle constituting the *umbilical cord* or *funiculus.* The latter originates, therefore, from the fusion of three chief components, the amniotic sheath, the belly-stalk, and the vitelline duct ; the belly-stalk.

as already noted, includes the allantois, with its blood-vessels, and diverticulum, while traces of the vitelline circulation are for a time visible within the atrophied walls of the umbilical duct. As gestation advances, the amnion and the chorion become closely related, but not inseparably united ; between these attenuated membranes lie the remains of the once voluminous yolk-sac, which at birth appears as an inconspicuous vesicle, from three to ten millimetres in diameter, situated usually several centimetres beyond the insertion of the umbilical cord.

In cases in which the closure and the obliteration of the vitelline duct before birth are imperfectly effected, a portion, or even the whole, of the intra-embryonic segment of the canal may persist as a pervious tube. Although in extreme cases of faulty closure a passage may lead from the digestive tube to the umbilicus, and later open upon the exterior of the body as a congenital umbilical anus, the retention of the lumen of the vitelline duct is usually much less extensive, being limited to the proximal end of the canal, where it is known as *Meckel's diverticulum*. The latter is connected with the ileum at a point most frequently about 82 centimetres (thirty-two inches) from the ileo-cæcal valve. Such diverticula usually measure from five to 7.5 centimetres in length, and possess a lumen similar to that of the intestine with which they communicate.

The foregoing envelopes, the amnion and the chorion, are the product of the embryo itself ; their especial purpose, in addition to affording protection for the delicate organism, is to aid in establishing close nutritive relations between the embryo and the maternal tissues, which, coincidently with the development of the fœtal envelopes, undergo profound modifications ; these changes must next be considered.

The Deciduæ.—The birth of the child is followed by the expulsion of the after-birth, consisting of the membranes and the placenta, which are separated from the uterine wall by the contractions of this powerful muscular organ. Close inspection of the inner surface of the uterus and of the opposed outer surface of the extruded after-birth shows that these surfaces are not smooth, but roughened, presenting evidences of forcible separation. The fact that the external layer of the expelled after-birth consists of the greater portion of the modified mucous membrane which is stripped off at the close of parturition suggested the name *deciduæ* for the maternal portion of the fœtal envelopes shed at birth.

Since the deciduæ are directly derived from the uterine mucous membrane, a brief sketch of the normal character of the last-named structure appropriately precedes a description of the changes induced by pregnancy. The normal mucous membrane lining the body of the human uterus (Fig. 51) presents a smooth, soft, velvety surface, of a dull reddish color, and measures about one millimetre in thickness. The free inner surface is covered with columnar epithelium (said to be ciliated) which is continued directly into the uterine glands. The latter, somewhat sparingly distributed, are cylindrical, slightly spiral depressions, the simple or bifurcated blind extremities of which extend into the deeper parts of the mucosa in close relation to the inner bundles of involuntary muscle ; all parts of the tubular uterine glands are lined by the columnar epithelium. The muscular bundles representing the muscularis mucosæ are enormously hypertrophied and constitute the greater part of the inner more or less regularly disposed circular layer of the uterine muscle. The unusual development of the muscular tissue of the mucous membrane reduces the submucous tissue to such an insignificant structure that the submucosa is generally regarded as wanting, the extremities of the uterine glands being described as reaching the muscular tunic. The glands lie embedded in the connective-tissue complex, rich in connective-tissue elements and lymphatic spaces, that forms the tunica propria of the mucosa.

With the beginning of pregnancy the uterine mucous membrane undergoes marked hypertrophy, becoming much thicker, more vascular, and beset with numerous irregularities of its free surface caused by the elevations of the soft spongy component tissue. These changes take place during the descent of the fertilized ovum along the oviduct and indicate the active preparation of the uterus for the reception of the ovum.

According to the classical description of the encapsulation of the ovum (Fig. 52) by the uterine mucous membrane, the embryonic vesicle becomes arrested within

one of the depressions of the uterine lining, usually near the entrance of the oviduct, whereupon the adjacent mucosa undergoes rapid further hypertrophy, which results in the formation of an annular fold surrounding the product of conception. This encircling wall of uterine tissue continues its rapid growth until the embryonic vesicle is entirely enclosed within a capsule of modified mucous membrane, known as the *decidua reflexa*, as distinguished from the *decidua vera*, the name applied to the general lining of the pregnant uterus. That portion of the uterine mucosa, however, which lies in close apposition to the embryonic vesicle, constituting the outer wall of the decidual sac, is termed the *decidua serotina ;* later it becomes the maternal part of the placenta.

FIG. 51.

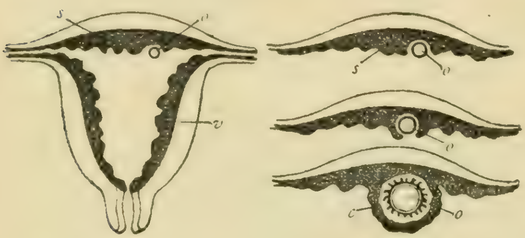
Uterine mucous membrane with part of muscular tissue. × 45.

Our knowledge of the details regarding the encapsulation of the ovum has been materially advanced by the recent observations of Peters, who had the rare good fortune of carefully studying the details of the process at an earlier stage than any hitherto accurately investigated. The results of Peters's observations lead to a somewhat modified conception of the early phases of the encapsulation of the ovum, as well as shed additional light on some of the vexed problems concerning the details of the formation of the placenta.

According to these investigations, the embryonic vesicle, on reaching the uterine

cavity and becoming arrested at some favorable point, usually in the vicinity of the oviduct, brings about a degeneration of the uterine epithelium over the area of contact. The disappearance of the epithelial lining is followed by sinking and embedding of the embryonic vesicle within the softened mucous membrane, the process being accompanied by erosion of some of the uterine capillaries and consequent hemorrhage into the opening representing the path of the ovum. The extravasated blood escapes at the point of entrance on the uterine surface and, later, forms a mushroom-shaped plug marking the position of the embedded ovum. The latter thus comes into closer relations with the maternal tissues at an earlier period than was formerly recognized.

FIG. 52.



Diagrams representing relations of the uterine mucous membrane to the embryonic vesicle, or ovum, during the embedding of the latter. *s*, *v*, *c*, decidua serotina, vera, and reflexa, respectively; *o*, ovum.

The Trophoblast. — The earliest human embryonic vesicle that has been accurately studied, — that of Bryce and Teacher, — measuring only 1 millimetre in its greatest diameter, was already enclosed externally by a conspicuous ectoblastic envelope, consisting of an outer and an inner cell-layer. This thick ectoblastic layer is evidently the proliferated trophoblast (page 31), a membrane so designated to indicate the important nutritive functions which it early assumes.

Very early the trophoblast becomes honeycombed by the extension of the maternal vascular channels into the ectoblastic tissue (Fig. 53), which consequently is broken up into irregular epithelial trabeculæ separating the maternal blood-spaces. The inner surface of the trophoblastic capsule presents numerous irregular depressions into which corresponding processes of the adjacent young mesoblast project; this arrangement foreshadows the formation of the chorionic villi which soon become so conspicuous in the human embryonic vesicle. Coincidently with the invasion of the trophoblast by the vascular lacuna externally and the penetration of the mesoblastic tissue internally, the peripheral portions of the ectoblastic capsule undergo proliferation and extend more deeply into the surrounding maternal tissues. In consequence of the rapid growth of the embryonic vesicle, that part of the hypertrophied uterine mucosa which overlies the embedded embryonic vesicle soon becomes elevated and projects into the uterine cavity, thus giving rise to the structure described as the decidua reflexa, or, preferably, the *decidua capsularis*.

FIG. 53.

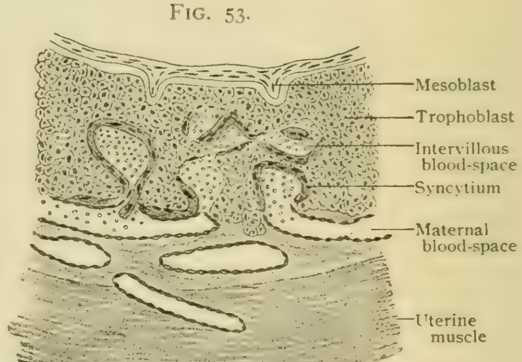


Diagram showing early stage of attachment between fœtal and maternal tissues; invasion of trophoblast by maternal blood-vessels. (*Peters.*)

The Decidua Vera. — The changes which affect the uterine mucous membrane, the decidua vera, result in great thickening, so that the mucosa often measures nearly a centimetre; this thickening, however, is most marked in the immediate vicinity of the embedded ovum, throughout the greater part of the uterus the decidua attaining a much less conspicuous hypertrophy. Towards the cervix the mucosa is least affected, and at the internal orifice of the cervical canal presents its normal appearance. Examination of the decidua shows that the normal constituents of the uterine mucosa undergo hypertrophy which results in enlargement of the uterine glands (Fig. 54), as well as in increase of the intervening connective-tissue stroma. The enlargement of the glands is not uniform, but is limited to the middle and terminal or deeper parts of

the tubular depressions; the inner portions of the glands, directed towards the surface of the uterus, become elongated and lie embedded within a comparatively dense matrix. In consequence of these changes, the decidua in the vicinity of the ovum, where the hypertrophy is most marked, presents in section two strata, an inner *compact* and an outer *spongy* layer. The ciliated columnar epithelium that normally clothes the free surface of the uterus, and perhaps also the uterine glands, gradually disappears, the degeneration beginning before the end of the first month. The integrity of the cells lining the uterine glands is maintained for a longer period, but the glandular epithelium likewise, after a time, suffers, losing its columnar character and changing to small cubical or flattened elements, which, after appearing as shrunken columns during the fourth and fifth months, finally disappear during the latter half of gestation. An important exception, however, is to be noted in the behavior of the epithelium lining the deeper portion, or the fundus, of the glands next the muscular tissue; the epithelium situated in this position does not participate in the atrophic changes above described, but retains more or less per-

FIG. 54.

Section of mucous membrane lining body of uterus (decidua vera); fourth month of pregnancy. (*After Leopold.*)

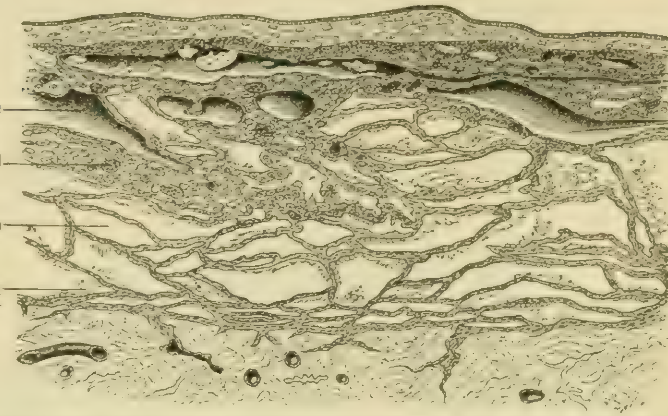
fectly its normal condition to the close of pregnancy. After the expulsion of the decidual portion of the uterine mucous membrane, the epithelium remaining in the fundus of the glands becomes the centre of regeneration for the new lining of the uterus.

The connective-tissue elements of the matrix surrounding the glands, especially in the compact layer in the vicinity of the ovum, undergo active proliferation, in consequence of which large spherical elements, the *decidual cells*, are produced. The latter, from .030 to .040 millimetre in diameter, in places are so densely packed that they assume the appearance of epithelium; although most typical and numerous in the compact layer, they are, nevertheless, present in the spongy stratum, in this situation being more elongated and lanceolate in form.

The decidua vera retains this general character during the first half of pregnancy; from this time on, however, the increasing volume of the uterine contents subjects the decidua to undue pressure, in consequence of which the hypertrophied mucosa undergoes the atrophic changes characteristic of the so-called second stage. These include a gradual reduction in the thickness of the decidua vera from nearly

one centimetre to about two millimetres, the disappearance of the ducts and openings of the uterine glands, and the conversion of the compact layer into a dense homogeneous stratum, in which the tightly compressed glands later entirely disappear. The spongy layer, on the contrary, retains the dilated gland-lumina, which, however, in consequence of pressure, are converted into irregular spaces arranged with their longest dimensions parallel to the uterine surface. The clefts next the

FIG. 55.

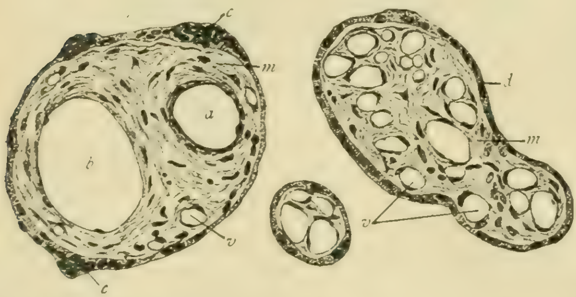


Section through fœtal membranes and uterus at margin of the placenta; sixth month of pregnancy. (*After Leopold.*)

muscular tissue are clothed with well-preserved epithelium; the lining cells of those towards the compact layer, on the contrary, early atrophy and disappear.

The Decidua Placentalis.—The decidua placentalis, or *decidua serotina*, being destined to contribute the maternal portion of the placenta, undergoes profound changes which particularly affect the blood-vessels of the mucosa. In addition to the initial general hypertrophy of the mucous membrane, which the placental decidua shares in common with other parts of the uterine lining, peculiar polynucleated elements, the *giant cells*, make their appearance during the fifth month; by the end of pregnancy they are found in large numbers within the basal plate and the septa of the placenta, although they are not wanting within the remains of the spongy layer. The giant cells are particularly numerous in the immediate vicinity of the large blood-vessels. The relations between the ingrowing fœtal trophoblastic tissue and the maternal structures early become so intimate within the placental area that especial modifications are instituted destined for the production of the vascular arrangement by which the maternal and fœtal blood-streams are brought into close relations.

FIG. 56.



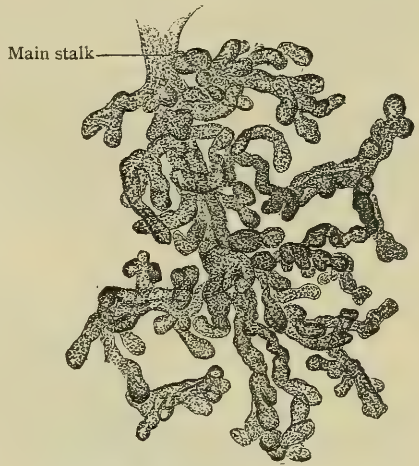
Sections of chorionic villi from placenta. × 170. *a*, *b*, small branches of umbilical artery and vein; *v*, capillary vessels; *c*, cell-aggregations of syncytium (*d*); *m*, mesoblastic stroma of villi.

The proliferating trophoblastic tissue invades the stroma of the mucous membrane and encroaches upon the capillaries until the latter in places become ruptured, allowing the escape of the maternal blood, which thus is brought into direct contact with the trophoblast. The erosion effected by the blood, on the one hand, and the encroachment of the fœtal mesoblast, on the other, gradually reduces the trophoblastic stratum, which is broken up into narrow epithelial trabeculæ separating the rapidly enlarging vascular lacunæ, the primary representatives of the intervillous

maternal blood-spaces of the placenta. The active outgrowth of the mesoblastic tissue of the chorion into the trophoblastic envelope results in the production of the characteristic villous condition distinguishing the early human embryonic vesicle.

When sectioned, the well-developed *chorionic villi* are seen to be composed of two portions, (*a*) the central core of gelatinous connective tissue, containing numerous stellate cells and blood-vessels, representing the fœtal mesoblast, and (*b*) the epithelial covering derived from the trophoblast. The investment of the villi consists of two layers,—an inner stratum, next the connective-tissue core, composed of low, distinctly outlined polyhedral cells, the *chorionic epithelium*, and an outer stratum, the *syncytium*, composed of an apparently continuous protoplasmic layer, in which nuclei are visible, but definite cell boundaries are wanting. Irregularly distributed aggregations of nuclei, or *cell-patches* (Fig. 56), form slight elevations on the surface of the villi. The derivation of the outer layer, or syncytium, has been the subject of much discussion ; its close relation to the maternal blood-spaces suggested a maternal origin to some investigators, while others regard it as a fœtal production. The observations of Peters on the very early human ovum, already mentioned, conclusively show the correctness of the latter view, and that the syncytium is formed by the transformation of the trophoblast next the vascular lacunæ (Fig. 58) ; the syncytium, as well as the remaining parts of the villi of the chorion, therefore, is of fœtal origin. The epithelium covering the villi of the placental area early evinces a tendency towards regression, and by the fourth month exists only as isolated patches ; during the later stages, and particularly on the larger villi, the layer of chorionic epithelium disappears, the syncytium remaining as the sole attenuated covering of the connective-tissue core of the villi. In certain parts of its extent, especially where it covers the chorion and the decidua serotina,

FIG. 57.



Isolated tuft of chorionic villi from placenta. × 38.

FIG. 58.

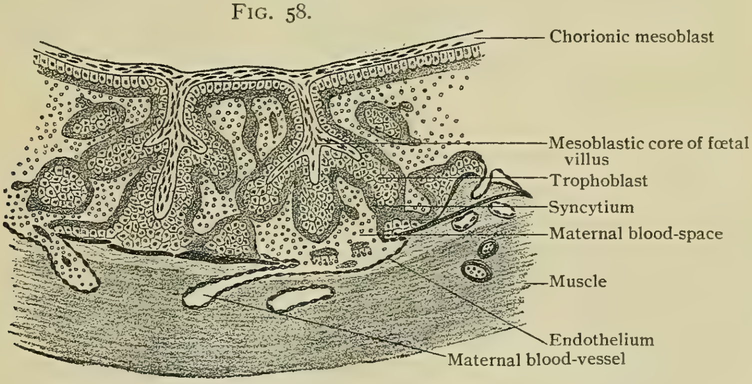


Diagram showing formation of placenta. (*Peters.*)

as well as upon some of the villi, the syncytium undergoes degeneration and is replaced by a peculiar layer of hyaline refracting material known as *canalized fibrin*.

The Placenta.—The placenta constitutes, from the third month of intra-uterine life, the nutritive and respiratory organ of the fœtus. As seen at birth, it is of irregular discoidal form, concavo-convex in section, and measures from fourteen to eighteen centimetres in diameter and from three to four centimetres in thickness.

Its convex external or uterine surface is rough, owing to the separation from the deeper part of the lining of the uterus which has taken place at the termination of labor. This surface, moreover, presents a number of divisions, the *cotyledons*, defined by deep fissures. The inner or fœtal surface is smooth, being covered by the amnion, and slightly concave. The weight of the fully developed placenta averages about 500 grammes.

The position of the placenta is determined, evidently, by the point at which the ovum forms its attachment with the maternal tissues ; in the majority of cases this location is at the fundus of the uterus in the vicinity of the oviduct, right or left, the orifice of which becomes occluded by the expansion of the placental structures. Less frequently the placenta occupies the more dependent portions of the uterine wall and, in exceptional cases, its position is in the immediate vicinity of the internal mouth of the uterus ; in these latter cases the placenta may partially, or even completely, grow over the latter opening, thus constituting the grave condition known as placenta prævia. The general constitution of the placenta (Fig. 59), as consisting

FIG. 59.

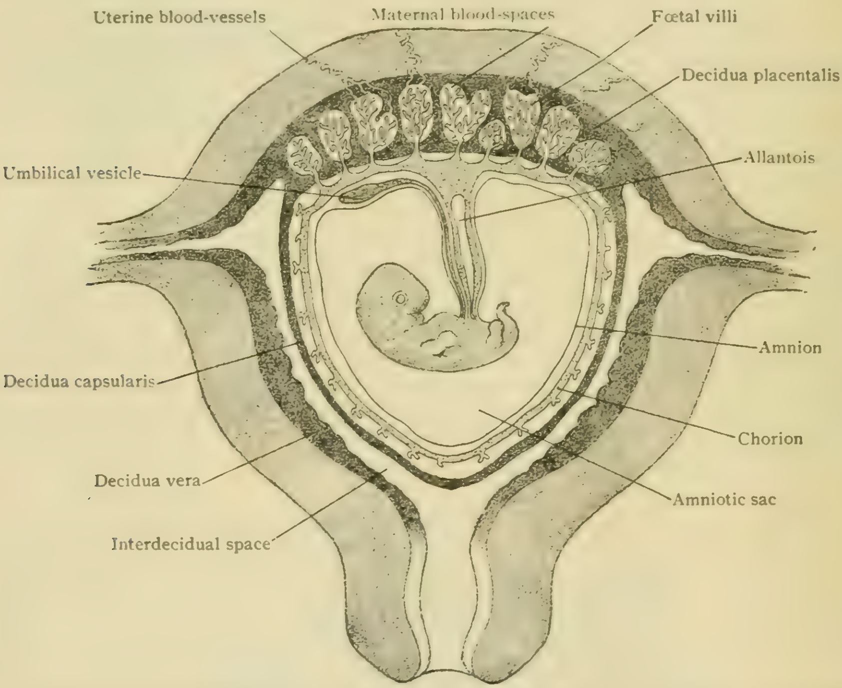


Diagram illustrating the relations of the fœtus, the membranes, and the uterus during the early months of pregnancy.

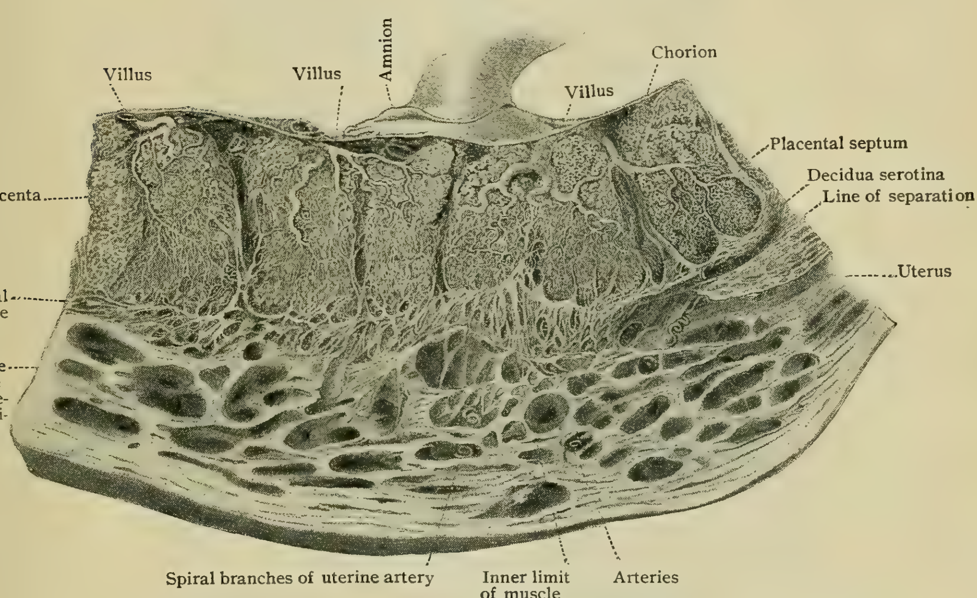
of the fœtal and the maternal portions, has already been sketched ; it now remains to consider briefly the arrangement of these structures.

The *fœtal portion* of the placenta, the contribution of the chorion frondosum, soon becomes a mass of richly branching villi, the more robust main stalks of which are attached to the maternal tissue, while the smaller secondary ramifications are free, completely surrounded by the contents of the maternal blood-sinuses in which they float. In all cases the villous processes support the terminal loops of the fœtal blood-vessels, the blood being conveyed to and from the placenta, along the umbilical cord, by the umbilical arteries and vein. Although coming into close relation, the syncytium and the meagre connective tissue surrounding the fœtal capillaries alone intervening, the blood-streams of the mother and of the child never actually mingle ; the delicate septum, however, allows the free interchange of gases necessary for the respiratory function as well as the passage of nutritive substances into the fœtal circulation.

The *maternal portion* of the placenta is contributed by that portion of the uterine mucous membrane known as the decidua serotina ; its especial peculiarities consist in the intervillous blood-spaces, which may be regarded as derivations from the eroded maternal blood-vessels. As already described, the trophoblast and maternal tissues early come into close relation, and the capillary blood-vessels are opened by the invasion of the fœtal tissue, which latter, in turn, is eroded and channelled out by the maternal blood which escapes upon the rupture of the blood-vessels of the mucosa. The extension of the blood-spaces thus originating constitutes the elaborate system of vascular lacunæ, or *intervillous spaces*, forming so conspicuous a part of the fully developed placenta.

In its earlier changes the decidua serotina closely resembles the decidua vera, presenting an inner compact and an outer spongy layer ; by the middle of pregnancy, however, the previously enlarged glands have entirely disappeared in consequence of the atrophy induced by the increasing pressure caused by the augmenting volume of the uterine contents. When the placenta is detached from the uterus the

FIG. 60.



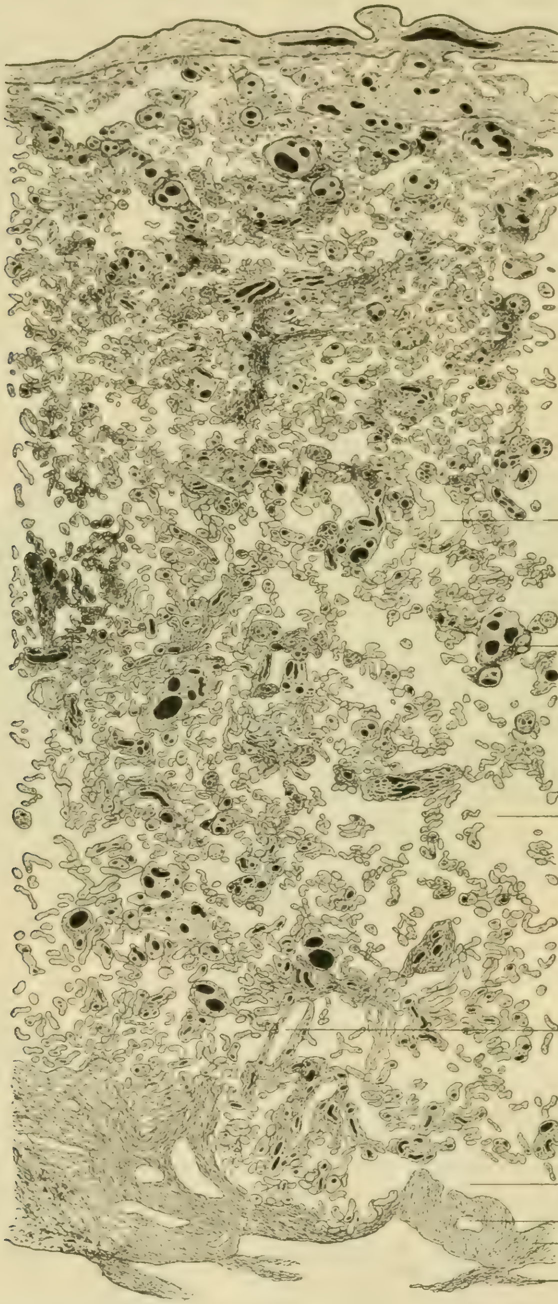
Section of placenta and uterus at the seventh month. (*Ecker.*)

line of separation passes through the junction of the former spongy and compact layers ; according to Webster, however, the separation occurs in the compact layer. The condensed decidual tissue closing in the vascular lacuna, on the one hand, and covering the surface of separation, on the other, constitutes the *basal plate.* The latter is continued deeply within the placenta by connective-tissue portions, the *septa placentæ*, which extend between the groups of chorionic villi, forming the cotyledons visible on the outer surface of the placenta as irregular lobules separated by deep furrows. These septa do not reach as far as the chorion except at the margin of the placenta, where they form a thin membranous sheet beneath the chorion, the *subchorionic occluding plate* of Waldeyer. Large, round, multinucleated elements, the *giant cells*, measuring from .04 to .08 millimetre in diameter, are present within the tissue of the maternal placenta, especially within the basal plate and the septa. At the margin the placental tissue becomes directly continuous with the fœtal membranes, the chorion and the decidua being closely united.

The numerous branches of the arteries supplying the uterus pierce the muscular tunic and gain the basal plate ; here the arterial vessels lose their muscular coat and

penetrate the placental septa as spirally directed channels of enlarged calibre bounded by endothelial walls. After a shorter or longer course within the septa, the arterial

FIG. 61.

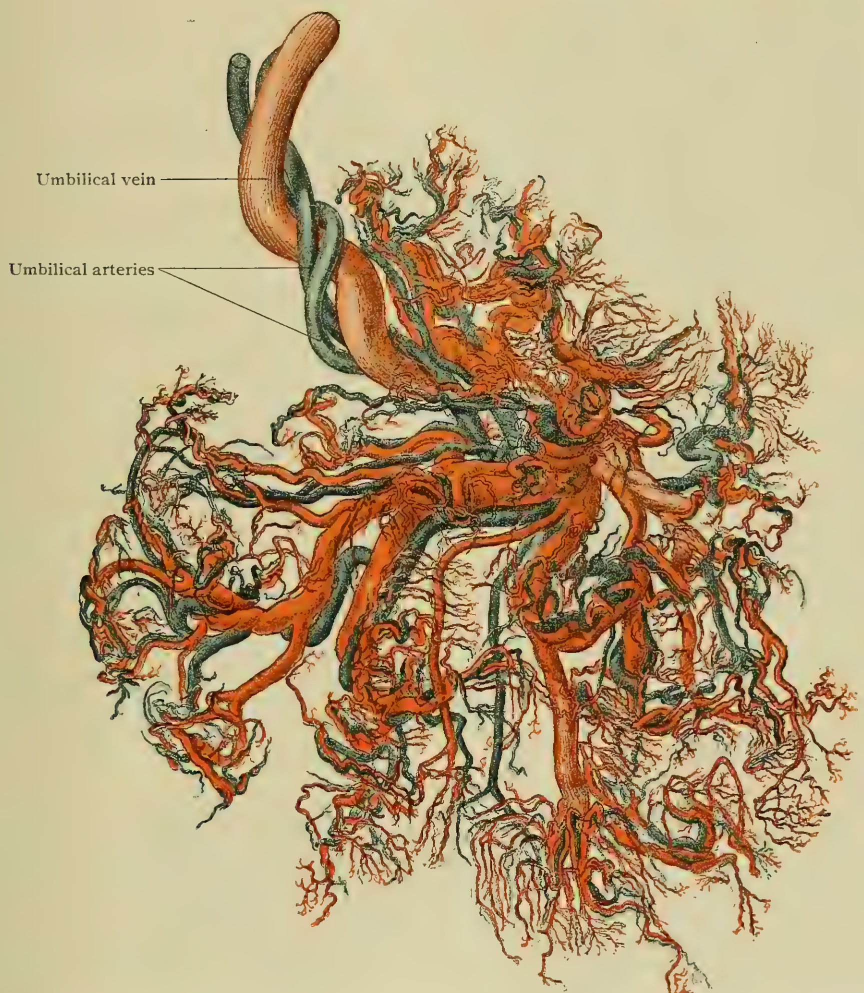


Section of human placenta at end of pregnancy. × 12. The fœtal blood-vessels have been injected; the maternal blood-spaces appear as clear areas surrounding the sections of the fœtal villi.

trunks open directly into the intervillous or intraplacental blood-spaces which are limited by the chorion and the villi on the one side and by the septa and basal plate

on the other. Maternal capillaries are wanting within the placenta, since they have become early replaced by the intervillous lacunæ. The maternal blood is carried away from these spaces by wide venous channels which pass directly from the lacunæ through the placental septa into the basal plate, where they form net-works from which proceed the larger venous trunks. At the edge of the placenta the anastomosing cavernous spaces form an annular series of intercommunicating venous channels known collectively as the *marginal sinus*, into which empty numerous placental veins, on the one hand, and from which, on the other, pass tributaries to the larger veins of the uterus.

FIG. 62.



Corrosion preparation of human placenta, showing general grouping of fœtal vessels into lobules.

The Umbilical Cord.—The umbilical cord, or *funiculus umbilicalis*, which connects the body of the fœtus with the placenta, thereby conveying the fœtal blood to and from the respiratory and nutritive apparatus, is formed in consequence of the fusion of three originally distinct structures,—the belly-stalk, the vitelline stalk, and the amnion. The first of these, in addition to forming the early attachment of the fœtus to the chorion, supports the rudimentary allantoic canal and the allantoic, later umbilical, blood-vessels. The vitelline stalk encloses the diminishing vitelline duct and the remains of the vitelline blood-vessels, while surrounding these stalks the amniotic sheath gradually becomes more closely applied. These

three constituents of the cord lie embedded within the delicate stroma formed by the gelatinous connective tissue, the *jelly of Wharton*, surrounded externally by the common amniotic investment.

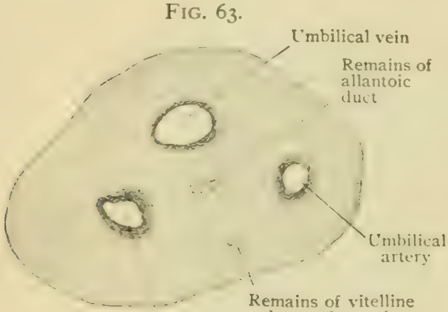
The details of the cord must necessarily vary with the period of gestation, since the component structures undergo marked changes. On section of the funiculus at the end of pregnancy, the following features may usually be distinguished :

(1) The *amniotic sheath*, which is closely united with the underlying connective tissue, except for a short distance beyond the umbilical opening, at which point the amnion may be separated as a distinct layer.

(2) The *jelly of Wharton* forms the common ground-substance in which the remaining constituents of the cord lie embedded. This tissue corresponds to the mucoid type, and contains a generous distribution of stellate connective-tissue cells which form a reticulum by their anastomosing processes.

(3) The *umbilical blood-vessels*—two arteries and one vein—are the most conspicuous components of the cord, since their size increases with the demands made by the growing fœtus. The markedly tortuous umbilical arteries usually entwine the single umbilical vein and slightly increase in lumen in their progress towards the placenta, in the immediate vicinity of which an anastomosis very constantly is to be found. Seldom in man, but always in certain mammals, as the mouse, the umbilical artery is single. According to His, even the youngest human cords possess only a single umbilical vein, except in the immediate vicinity of the placenta ; again, on entering the body of the fœtus the single vessel is represented by two umbilical veins which, for a time, course within the abdominal wall. The right vein, however, soon undergoes atrophy, while the left takes part in the formation of the hepatic circulation. Valves have been described within the umbilical vein. The latter shares with the pulmonary vein the distinction of conveying blood which has been oxygenated by respiratory function.

FIG. 63.



Transverse section of umbilical cord of third month. × 12.

(4) The *allantoic duct*, as a distinct canal, is usually obliterated by the third month of fœtal life ; at birth, however, atrophic remains, consisting of a narrow column of epithelial cells situated between the umbilical blood-vessels, are seen in sections of the cord taken from the vicinity of the navel.

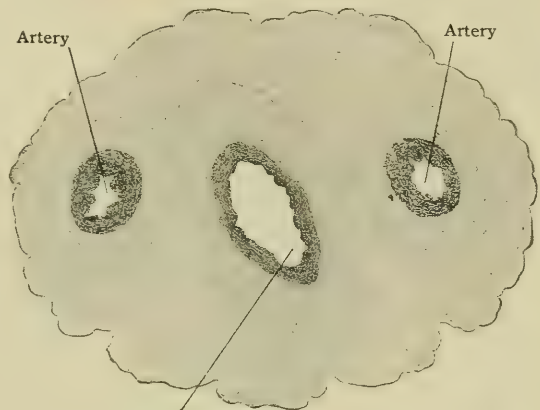
The stalk of the vitelline sac, or umbilical vesicle, enclosing the vitelline duct and supporting the vitelline, or omphalomesenteric, blood-vessels, is still present during the second month ; at this period it lies within the extension of the cœlom, which is continued into the young cord. With the early disappearance of this space the vitelline stalk and the associated structures disappear, and by the end of gestation usually all traces of these structures have vanished from the cord. The most conspicuous details of the umbilical cord at birth, therefore, are the three umbilical vessels, embedded within the gelatinous connective tissue and invested by the sheath of amnion.

The human umbilical cord is conspicuous on account of its exceptional length, which averages from fifty to sixty centimetres, while measuring only about twelve millimetres in thickness. The extremes of length include a wide range, varying from twelve to 160 centimetres (four and three-quarters to sixty-three inches).

The cord almost constantly exhibits a torsion, the spirals passing from left to right when traced towards the placenta. In addition to the general twisting of the cord, which begins towards the close of the second month, the umbilical arteries display even more marked spiral windings, usually enclosing the somewhat less twisted umbilical vein. The cause of this conspicuous torsion is probably to be sought in the spiral growth of the umbilical blood-vessels, the twisting of the cord, as well as the revolutions of the fœtus, being secondary.

While the attachment of the cord usually is situated near the middle of the placenta, it is seldom exactly central; the insertion is subject to great variation, however, the eccentricity sometimes being so great that the cord is fixed to the periphery of the placenta, such disposition constituting *insertio marginalis*. Among the more exceptional variations in the arrangement of the cord are the cleft and the extraplacental attachment known respectively as *insertio furcata* and *insertio velamentosa*. In the former condition, where the cord divides before reaching the placenta, each limb conveys one of the umbilical arteries and a branch of the umbilical vein. When the insertion of the cord is into the chorion entirely outside the placental area, in exceptional cases being as far removed as the opposite pole of the membranous capsule, the umbilical vessels course within the non-villous portions of the chorion until they reach the fœtal placenta. In addition to the true knots, which often occur and are due to the excursions of the fœtus, the umbilical cord sometimes presents nodular thickenings and irregular constrictions, as well as projections formed by loops and varicosities of the blood-vessels.

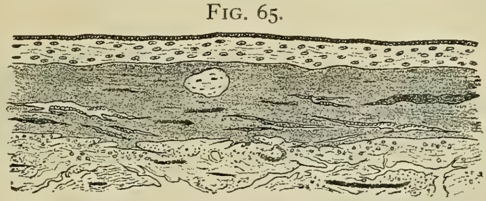
FIG. 64.



Transverse section of umbilical cord at end of pregnancy, taken from placental end; the umbilical blood-vessels are embedded within the embryonal connective tissue. × 10.

The After-Birth.—The expulsion of the child through the rupture in the enveloping membranes, which is produced by the powerful contractions of the uterine muscle at the close of pregnancy, is followed, after a short interval, by the separation and expulsion of the "after-birth;" under this term are included the placenta and the enveloping membranes. The latter, as will be understood from the foregoing consideration of the encapsulation of the fœtus, consist of three chief constituents,—the remains of the decidua vera, the chorion, and the amnion; the reflexa undergoes complete absorption. Since the decidua represents the shed portion of the modified uterine mucosa, the outer surface of the after-birth appears rough and studded with shreds of uterine tissue; the inner surface of the decidua is so closely fused with the adjacent chorion by means of delicate connective tissue that only a limited and uncertain separation is possible. The amnion, on the other hand, although attached to the chorion by bands of connective tissue, may be peeled off the chorion with relative ease, since the union between the two membranes is never firm. The inner ectoblastic surface of the amnion in contact with the fœtus is smooth and bathed in the liquor amnii. The external and unshed portion of the modified uterine mucosa contains the inconspicuous remains of the epithelium lining the fundus of the glands: these elements are of the utmost importance for the regeneration of the glandular and epithelial tissues of the new uterine mucous membrane, since the reparation of these structures, which is effected within a few weeks after labor, begins in the proliferation of the deeper glandular epithelium, which remains throughout pregnancy as the latent source of subsequent repair.

FIG. 65.



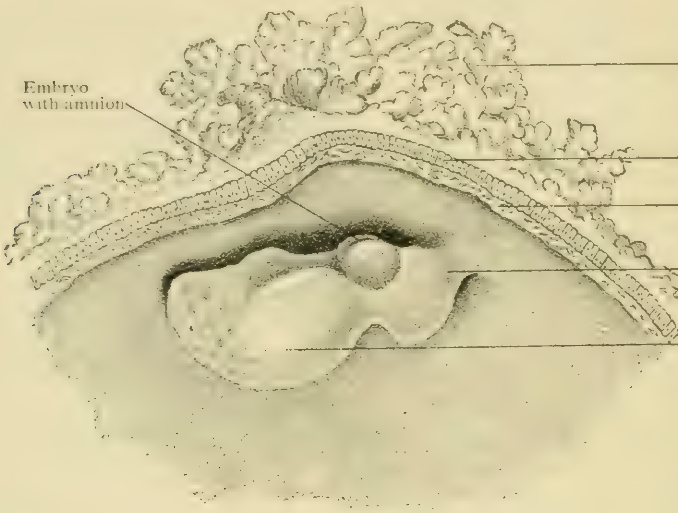
Section through fœtal membranes and uterus at end of pregnancy. (*After Leopold.*)

DEVELOPMENT OF THE GENERAL BODY-FORM.

In considering the evolution of the external form of the human product of conception, it is convenient to recognize the three developmental epochs suggested by His,—the stage of the ovum, the stage of the embryo, and the stage of the fœtus.

The Stage of the Blastodermic Vesicle.—This stage, or the *stage of the ovum*, embraces the first two weeks of intra-uterine life, during which the initial phases of development, including fertilization, segmentation, and the formation of the blasto-

FIG. 66.

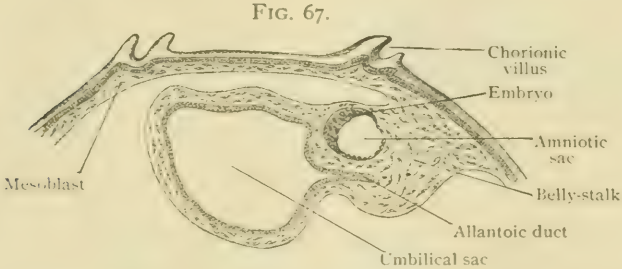


Early human embryonic vesicle of about thirteen days laid open, showing the young embryo (.37 millimetre long) attached to the wall of the serosa by means of the belly-stalk. × 25. (*After Spee.*)

dermic vesicle, are completed, and the fundamental processes resulting in the differentiation of the medullary tube, the notochord, the somites, and the mesoblastic plates are begun. The early details of many of these processes have never been observed in man, but there is little reason to doubt that in its essential features the early human embryo closely follows the changes directly observed in other mammals.

The Stage of the Embryo.—The stage of the embryo, from the second to the fifth week, is distinguished by the formation of organs essentially embryonic and transient in character, as the somites, the notochord, the Wolffian body, and the visceral arches.

FIG. 67.



Section of preceding embryonic vesicle and embryo. × 25. (*After Spee.*)

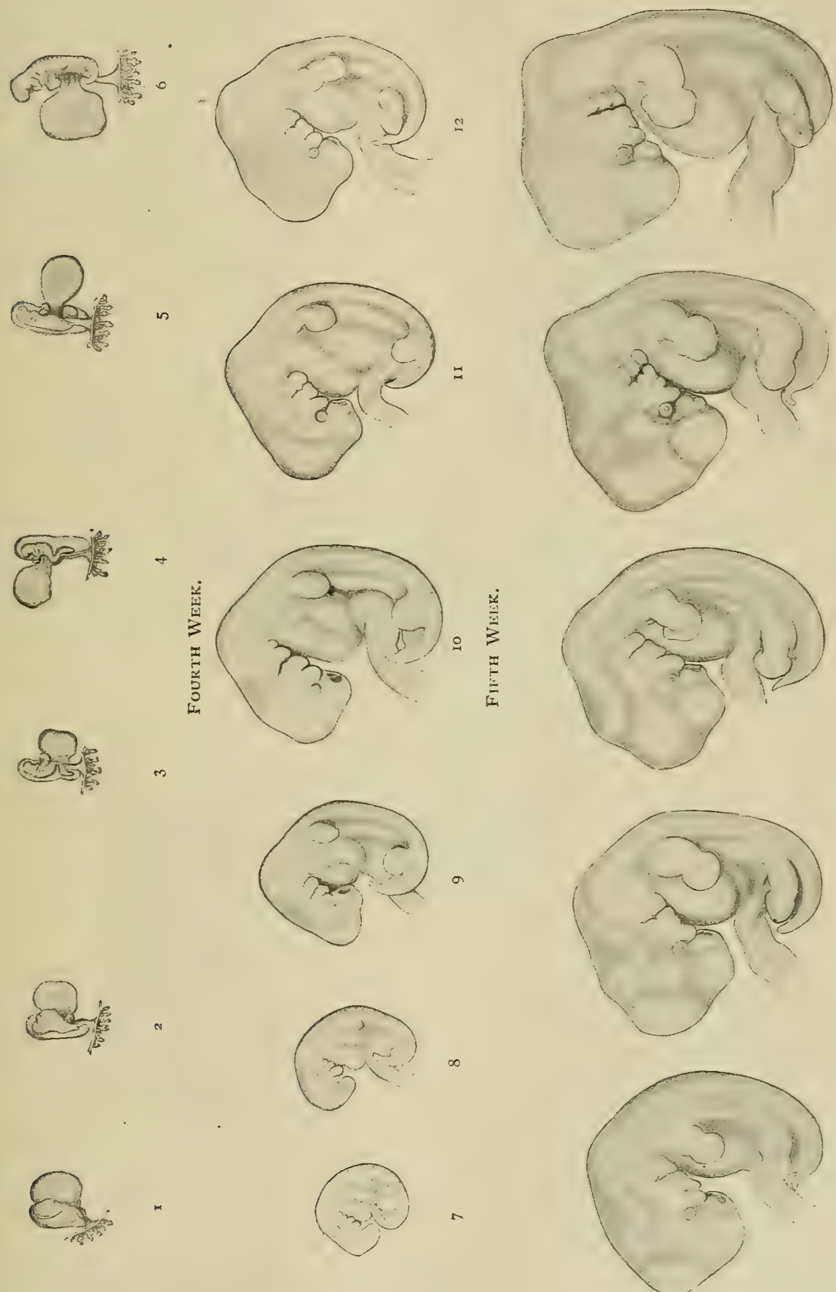
The earliest phase in the differentiation of the vertebrate body-form consists in the establishment of a dorsal tube by the apposition and fusion of the ectoblastic medullary folds, and a ventral tube by the approximation and final union of the folds directly derived from the somatopleura. The dorsal, or *animal*, tube represents the early neural canal, and becomes the great cerebro-spinal nervous axis; the ventral, or *vegetative*, tube, formed by the ventral extension and approximation of the somatopleura, constitutes the body-cavity, and encloses the primary gut and the associated thoracic and abdominal viscera, and the vascular system. The primitive gut-tube originates by the delimitation of a part of

the vitelline sac accomplished by the ventral approximation of the splanchnopleura, and for a time maintains a wide communication with the remains of the yolk-cavity.

The early embryo, lying flatly expanded upon the blastodermic vesicle, becomes differentiated in form by the appearance of head- and tail-grooves, in consequence of

Fig. 68.

Second and Third Weeks.



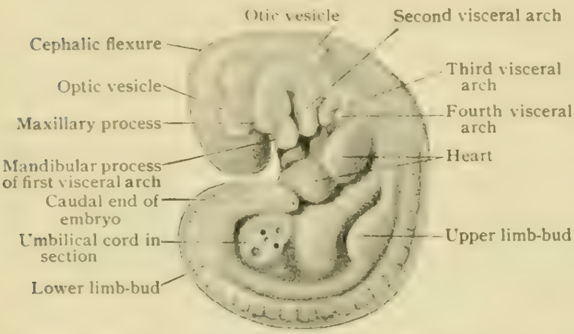
Type-plate of early human embryos, all enlarged three diameters. (*His.*) 1–4, from twelfth to fifteenth day; 5, 6, from eighteenth to twenty-first day; 7, 8, from twenty-third to twenty-fifth day; 9–12, from twenty-seventh to thirtieth day; 13–17, from thirty-first to thirty-fourth day.

which constriction the cephalic and the caudal poles of the body become defined and partially separated from the embryonal area; the middle segment, however, embracing the widely open gut-tract, for a time remains closely blended with the vitelline sac, of which, at first, the embryo appears as an appendage (Fig. 68, 1 and 2).

The more complete differentiation of the digestive tube and the ventral folding in of the body-walls change this relation, the rapidly decreasing umbilical vesicle soon becoming secondary to the embryo.

At the close of the stage of the blastodermic vesicle—about the fifteenth day—the embryo possesses a general cylindrical body-form, the dilated cephalic pole being free, while the belly-stalk attaches the caudal segment to the chorion; the amniotic sac invests the dorsal aspect, the large umbilical vesicle occupying the greater part of the ventral surface. Human embryos of the fourteenth and fifteenth days (Fig. 68, 3 and 4) are distinguished by a conspicuous flexure opposite the attachment of the umbilical vesicle, the convexity being directed ventrally, the deep corresponding concavity producing a marked change of profile in the dorsal outline. During these changes the expansion of the cerebral segments outlines the three primary divisions of the cephalic portion of the neural tube, the *anterior*, the *middle*, and the *posterior brain-vesicles*.

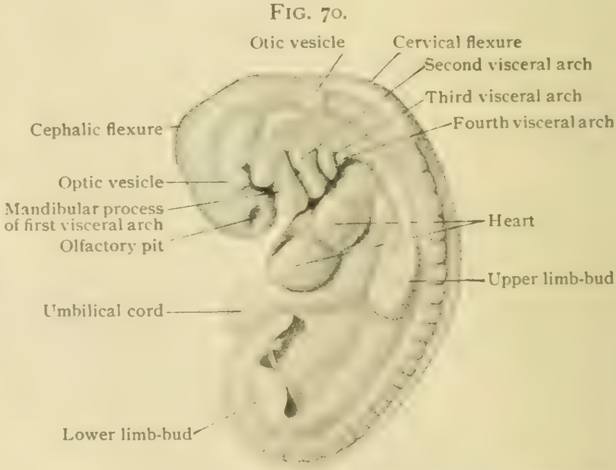
FIG. 69.



Human embryo of about twenty-three days, drawn from the model of His. × 10.

A little later a series of conspicuous bars, the *visceral arches*, appears as obliquely directed parallel ridges on either side of the head, immediately above the prominent heart-tube, which is now undergoing marked torsion. By the nineteenth day the dorsal concavity, which is peculiar to the human embryo, has entirely disappeared, the profile of this part of the embryo presenting a gentle convexity; the cephalic axis, however, exhibits a marked bend, the *cephalic flexure*, in the vicinity of the middle cerebral vesicle, in consequence of which the axis of the anterior cerebral segment lies almost at right angles to that of the middle vesicle. The completion of the third week finds the characteristic details of the cephalic end of the embryo, the cerebral, the optic, and the otic vesicles, and the visceral arches and intervening furrows well advanced, with corresponding definition of the primitive heart and the umbilical stalk and vesicle. The limb-buds usually appear about this time, those of the upper extremity slightly preceding those of the lower.

FIG. 70.



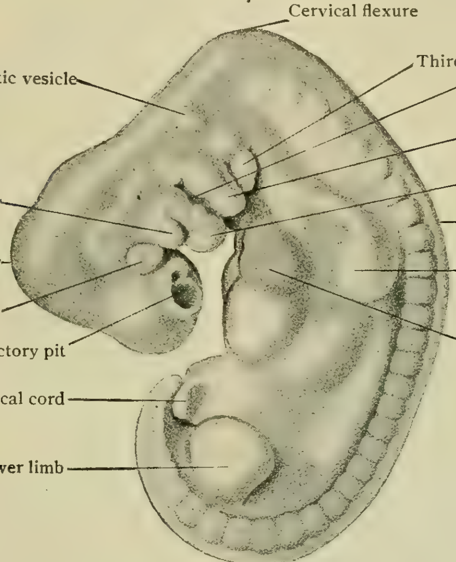
Human embryo of about twenty-five days, drawn from the model of His. × 10.

The period between the twenty-first and the twenty-third days witnesses remarkable changes in the general appearance of the embryo; in addition to greater prominence of the visceral arches, the cerebral segments, and the limb-buds, the embryonic axis, which, with the exceptions already noted, up to this time is only slightly curved, now undergoes flexion to such extent that by the twenty-third day the overlapping cephalic and caudal ends of the embryo are in close apposition, the body-axis describing rather more than a complete circle (Fig. 69).

From the twenty-third to the twenty-eighth day the excessive flexion gradually disappears, owing to the increased volume of the heart and the growth of the head, and by the end of the fourth week the embryo has acquired the most characteristic development of the embryonic stage (Fig. 71). The reduction in the curvature of the body-axis and the consequent separation of its poles and the raising of the head are accompanied by the appearance of four well-marked axial flexions, the *cephalic*, the *cervical*, the *dorsal*, and the *sacral flexures* (Fig. 71). The first of these, the cephalic, is an accentuation of the primary flexure, which is seen as early as the eighteenth day, and is indicated by the projection of the midbrain ; it corresponds in position to the future sella turcica. The second and very conspicuous bend, the cervical flexure, marks the caudal limit of the cephalic portion of the neural axis, and agrees in position with the subsequent upper cervical region. The dorsal and sacral flexures are less well defined, the former being situated opposite the upper limb-bud, where the cervical and dorsal series of somites join, the latter, near the lower limb-bud, corresponding with the junction of the lumbar and sacral somites.

The cephalic segment at this stage presents numerous prominent details, the

FIG. 71.



Human embryo of about twenty-eight days, drawn from the model of His. × 10.

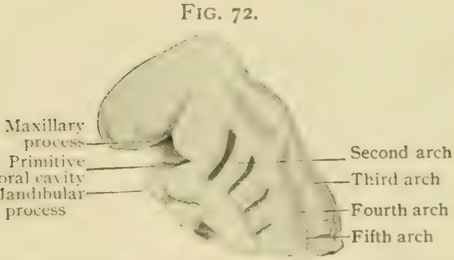
secondary cerebral vesicles, the forebrain, the interbrain, the midbrain, the hindbrain, and the after-brain, the visceral arches and furrows, the optic and otic vesicles, the olfactory pits, and the primitive oral cavity all being conspicuous. The heart appears as a large protrusion, occupying the upper half of the ventral body-wall, on which the primary auricular and ventricular divisions are distinguishable. The somites form a conspicuous longitudinal series of paraxial quadrate areas, about thirty-seven in number ; they correspond to the intervertebral muscles, and may be grouped to accord with the primary spinal nerves, being, therefore, distinguished as eight cervical, twelve dorsal, five lumbar, five sacral, and five or more coccygeal somites.

THE VISCERAL ARCHES AND FURROWS.

Since the visceral arches are best developed in the human embryo during the last half of the third week, a brief consideration of these structures in this place is appropriate. The visceral arches in mammalian embryos constitute a series of five parallel bars separated by intervening furrows, obliquely placed on the ventro-lateral aspect of the cephalic segment, occupying the region which later becomes the neck. They represent, in rudimentary development, the important branchial or gill-

apparatus of water-breathing vertebrates, in which the respiratory function is performed by means of the rich vascular fringes lining the clefts through which the water passes, thus permitting the exchange between the oxygen of the water and the carbon dioxide of the blood. Each arch is supplied by a blood-vessel, or *aortic bow*, which passes from the main ventral stem, the *truncus arteriosus*, through the substance of the visceral arch backward to unite with the similar bows to form the *dorsal aortæ*. In aquatic vertebrates the aortic bows supply an elaborate system of secondary branchial twigs, which form rich capillary plexuses within the gills; in air-breathing vertebrates, however, in which these structures are only rudimentary, the main stems, the aortic bows, are alone represented. With the loss of function which follows the acquisition of aërial respiration in the higher vertebrates, the number of visceral arches is reduced from six, or even seven, as seen in fishes, to five, the fifth arch in man, however, being so blended with the surrounding structures that it is not visible externally as a distinct bar. In their condition of greatest perfection, as in fishes, each visceral arch contributes an osseous bar, which forms part of the branchial skeleton; these bony bars are represented in man and mammals by cartilaginous rods, which temporarily occupy the upper arches, for the most part entirely disappearing. When viewed in frontal section (Fig. 73), the mammalian visceral arches are seen as mesodermic cylinders imperfectly separated by external and internal grooves, the *visceral furrows* and the *pharyngeal pouches* respectively; this arrangement emphasizes another modification following loss of function,—namely, the conversion of the true visceral clefts of the lower forms into furrows,—since in man and mammals the fissures are closed by the *occluding membrane* formed by the apposition of the ectoblast and the entoblast at the bottom of the outer and inner furrows.

Fig. 72.



Head of human embryo of about twenty-one days, seen from the side, showing visceral arches and external visceral furrows. × 20. (*After His.*)

The First or Mandibular Arch early becomes differentiated into a short upper or *maxillary process* and a longer lower or *mandibular process*. The maxillary process, in conjunction with its fellow of the opposite side and the *fronto-nasal process*, which descends as a median projection from the head (Fig. 75), contributes the tissue from which the superior and lateral boundaries of the oral cavity and the nasal region are derived. The mandibular process joins with its mate in the mid-line and gives rise to the lower jaw and other tissues forming the inferior boundary of the primary oral cavity. The latter in its original condition appears as a widely open space leading into the primitive pharyngeal cavity; later the septum is formed which divides the oral from the nasal cavity. The mandibular process contains a cartilaginous rod, which for a time represents the corresponding bony arch of the visceral skeleton of lower types. The ventral and larger part of this rod, known as *Meckel's cartilage*, entirely disappears, the lower jaw being developed independently around this bar of cartilage; the upper end of the cartilaginous bar, however, persists and forms two of the ear-ossicles, the malleus and the incus.

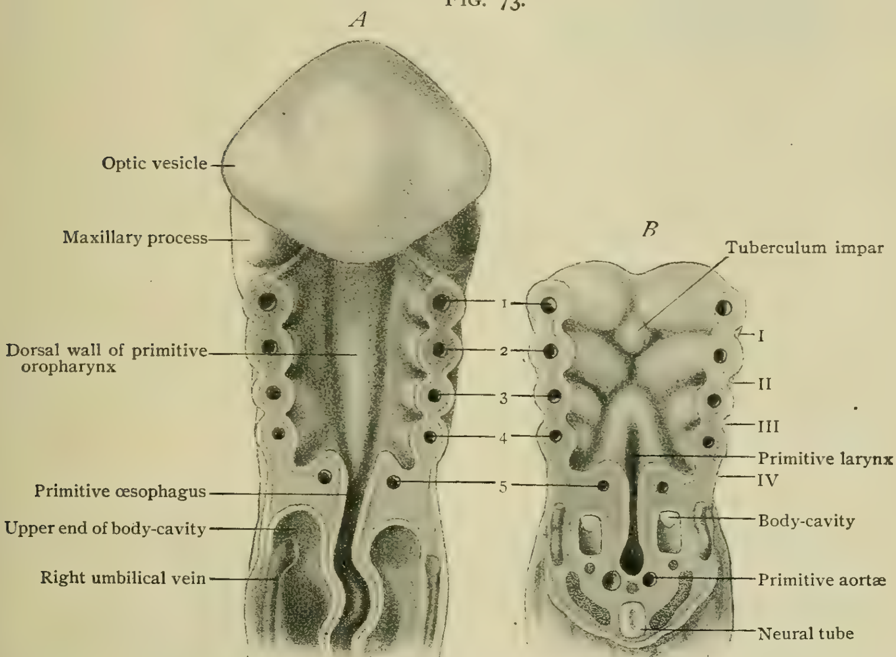
The Second or Hyoid Arch also contains a cartilaginous bar, from the ventral segment of which (known as the *cartilage of Reichert*) is derived the smaller cornu of the hyoid bone; the dorsal end of the bar, which is fused with the temporal bone, gives rise to the styloid process, the intervening portion of the cartilage persisting as the stylo-hyoid ligament. The cartilage of the second arch is also concerned in the formation of the stapes. The origin of this ear-ossicle is double, since the crura of the stapes are derived from the cartilage of the hyoid arch, while the base is contributed by the general cartilaginous capsule of the labyrinth. The characteristic form of the stapes is secondary and due to the perforation of the triangular plate, the early representative of this bone, which thus acquires its characteristic stirrup-shape in consequence of the penetration of a minute blood-vessel, the *perforating stapedial artery*, a branch of the internal carotid, which later disappears.

The Third or First Branchial Arch contains a rudimentary cartilaginous bar from which part of the body and the greater cornu of the hyoid bone are derived. The **fourth** and **fifth arches**, or **second** and **third branchial**, enclose rudimentary cartilaginous bars which early fuse into plates ; these unite along their ventral borders and give rise to the thyroid cartilage of the larynx.

The External Visceral Furrows (Fig. 73), the representatives of the true clefts of the lower types, appear with decreasing distinctness from the first towards the fourth ; the third and fourth early suffer modification, so that by the twenty-eighth day the first and second furrows alone are clearly defined.

The First Visceral Furrow, the *hyomandibular cleft*, undergoes obliteration except at its dorsal part, which becomes converted into the external auditory meatus, the surrounding tissue giving rise to the walls of the canal and the external ear. The remaining clefts gradually disappear, becoming closed and covered in by the overhanging corresponding arches ; this relation is particularly marked towards the

FIG. 73.



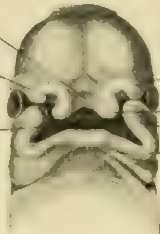
Upper half of human embryo of about eighteen days, drawn from His's models. × 45. *A*, dorsal wall of primitive oropharynx bounded by visceral arches, external and internal furrows. *B*, anterior wall of primitive oropharynx, seen from behind. 1–5, sections of aortic arches; I–IV, external visceral furrows.

caudal end of the series, where the sinking in of the arches and the included furrows produces a depression or fossa—the *sinus præcervicalis* of His—in the lower and lateral part of the future neck region. This recess subsequently entirely disappears on coalescence of the bordering parts ; sometimes, however, such union is defective, the imperfect closure resulting in a permanent fissure situated at the side of the neck, known as *cervical fistula*, by means of which communication is often established between the pharynx and the exterior of the body. Such communication must, however, be regarded as secondary, as originally the external furrows were separated from the primitive pharyngeal cavity by the delicate epithelial septum already mentioned as the occluding plate. Where entrance into the pharynx through the fistula is possible, it is probable that the septum has been destroyed as the result of absorption or of mechanical disturbance following the use of the probe.

The Inner Visceral Furrows, or *pharyngeal pouches*, repeat the general arrangement of the external furrows. The **first pharyngeal pouch** becomes narrowed and elongated, and eventually forms the Eustachian tube ; a secondary

dorsal expansion gives rise to the middle ear, while the occluding plate separating the outer and inner furrows supplies the tissue from which the tympanic membrane is formed. The **second furrow** in great part disappears, but its lower portion contributes the epithelium of the faucial tonsil and the supratonsillar fossa. The fossa of Rosenmüller is a secondary depression and probably does not represent the original furrow. The **third** and **fourth pouches** give rise to ventral entoblastic outgrowths from which the epithelial portions of the thymus and of the thyroid body are developed respectively. The last-named organ has an additional unpaired origin from the entoblast forming the ventral wall of the pharynx in the vicinity of the second visceral arch.

FIG. 74.



Head of human embryo of about twenty-seven days, showing boundaries of primitive oral cavity. × 7. (*After His.*)

The Development of the Face and the Oral Cavity.—The earliest suggestion of the primitive oral cavity is the depression, or *stomodæum*, which appears about the thirteenth day on the ventral surface of the cephalic end of the embryo immediately beneath the expanded anterior cerebral vesicle. The oral pit at first is separated from the adjacent expanded upper end of the head-gut by the delicate septum, the *pharyngeal membrane*, composed of the opposed ectoblast and the entoblast, which in this location are in contact without the intervention of mesoblastic tissue. With the rupture of the pharyngeal membrane, the deepened oral pit opens into the cephalic extremity of the head-gut, now known as the *primitive pharynx*.

The formation of the face is closely associated with the growth and fusion of the upper visceral arches in conjunction with the surrounding parts of the ventral surface of the head. The first visceral arch, as already described, presents two divisions, the *maxillary* and the *mandibular process*. The latter grows ventrally and joins in the mid-line its fellow of the opposite side, to form, with the aid of the second visceral arches, the tissues from which the lower boundary and the floor of the mouth are derived. The upper and lateral boundaries of the primitive oral cavity and the differentiation of the nasal region proceed from the modification and fusion of three masses, the two lateral paired maxillary processes of the first visceral arches and the mesial unpaired *fronto-nasal process*, which descends as a conspicuous projection from the ventral surface of the anterior part of the head. The maxillary processes grow towards the mid-line and, in conjunction with the descending fronto-nasal projection, form the lateral and superior boundary of the primitive oral cavity (Fig. 74). Very soon the development of the future nares is suggested by the appearance of slight depressions, the *olfactory pits*, one on each side of the fronto-nasal process; these areas constitute part of the wall of the forebrain, a relation which foreshadows the future close association between the olfactory mucous membrane and the cortex of the olfactory lobe.

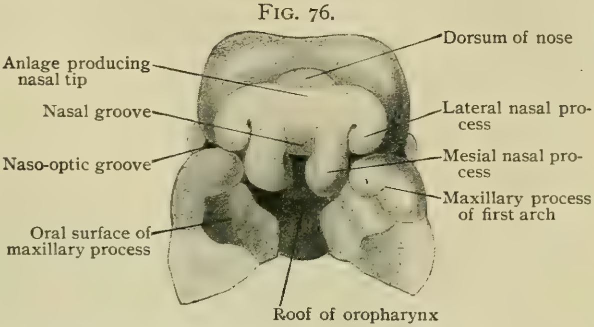
FIG. 75.

Head of human embryo of about thirty-four days. × 5. (*After His.*)

During the fifth week the thickened margins of the fronto-nasal process undergo differentiation into the *mesial nasal processes*, while coincidently the lateral portions of the fronto-nasal projection grow downward as the *lateral nasal processes*, these newly developed projections constituting the inner and outer boundaries of the rapidly deepening nasal pits. The line of contact between the lateral nasal process and the maxillary process is marked by a superficial furrow, the *naso-optic groove*,

which leads from the nasal pit to the angle of the eye ; this furrow, however, merely indicates the position of the naso-lachrymal duct which develops independently at the bottom of the primary groove. Reference to Figs. 74 and 75 emphasizes the fact that the nasal pits and the primitive oral cavity are for a time in widely open communication ; towards the close of the sixth week, however, the maxillary processes of the first arch have approached the mid-line to such an extent that they unite with the lateral margins of the fronto-nasal process as well as fuse with the lateral nasal processes above. Owing to this union of the three processes, the nasal pits become separated from the oral cavity, and with the appearance and completion of the palatal septum the isolation of the nasal fossæ from the mouth is accomplished. The lateral nasal processes contribute the nasal alæ, while from the conjoined mesial nasal process are developed the nasal septum and the bridge of the nose in addition to the middle portion of the upper lip and the intermaxillary segment of the upper jaw, the superior maxillary part of the latter being a derivative of the maxillary process of the first arch. Arrested development and imperfect union between the maxillary processes and the fronto-nasal process result in the congenital defects known as harelip and cleft palate, the degree of the malformation depending upon the extent of the faulty union.

FIG. 76.



Portion of head of human embryo of about thirty-four days, showing roof of primitive oral cavity. × 10. (*After His.*)

The Stage of the Fœtus.—The **fifth week** marks the completion of the period of development during which the product of conception has acquired the characteristic features of its embryonal stage ; beginning with the second month and continuing until the close of gestation, the succeeding *stage of the fœtus* is distinguished by the gradual assumption of the external features which are peculiar to the young human form. In addition to the already mentioned changes affecting the visceral arches and frontal process in the development of the face, the fifth week witnesses the differentiation of the limbs into segments, the distal division of the upper extremity exhibiting indications of the future fingers, which thus anticipate the appearance of the toes. The liver is already conspicuous as a marked protuberance occupying the ventral aspect of the trunk immediately below the heart. The head by this time has acquired a relatively large size, the prominent cephalic flexure which marks the position of the midbrain being particularly conspicuous. At the end of the fifth week, or the thirty-fifth day, the fœtus measures about fourteen millimetres in its longest dimension.

FIG. 77.

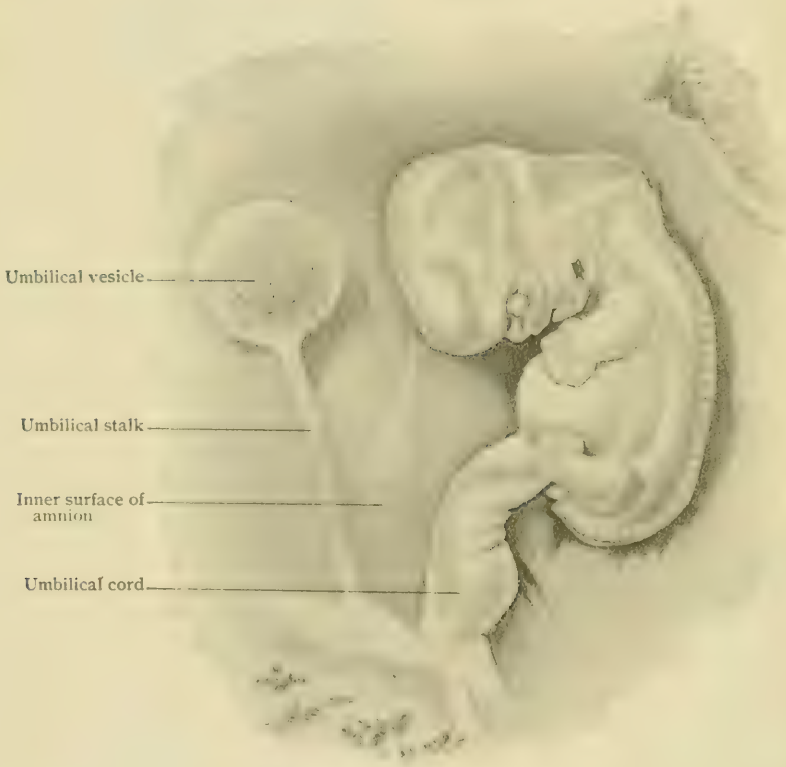
Head of human embryo of about seven weeks. × 5. (*After Ecker.*)

The **sixth week** finds the fœtus elongated with greater distinctness of the human form, the large size of the head, on which the cervical flexure is very evident, being highly characteristic when compared with corresponding stages of the lower mammals. The several constituents of the face become more perfectly formed, including the completion of the superior boundary of the oral cavity and its separation from the nasal pits by the septum resulting from the union of the fronto-nasal process with the maxillary processes ; the fusion of the latter with the lateral frontal processes now defines the external boundary of the nostrils of the still, however, broad and flattened nose, which lies immediately above the transverse cleft-like oral opening. The visceral arches are no longer visible as individual bars, having undergone complete fusion. The differentiation of the digits on both hands and feet has so far

progressed that fingers and toes are distinctly indicated, although the fingers only are imperfectly separated. The first suggestion of the external genitals appears about the end of the sixth week. At this time the fœtus measures about nineteen millimetres.

During the **seventh** and **eighth weeks** the fœtal form of the body and the limbs attain greater perfection, the large head becoming raised from the trunk and the toes, as well as fingers, being now well formed, although the rudiments of the nails do not appear until some time during the third month. At the close of the second month the extra-embryonic protrusion of the intestine through the umbilicus into the umbilical cord reaches its greatest extent. The genito-urinary system is represented by the fully developed Wolffian body, the vesical dilatation of the allantoic duct, the separation of the cloaca into rectum and genito-urinary passage, the indif-

FIG. 78.

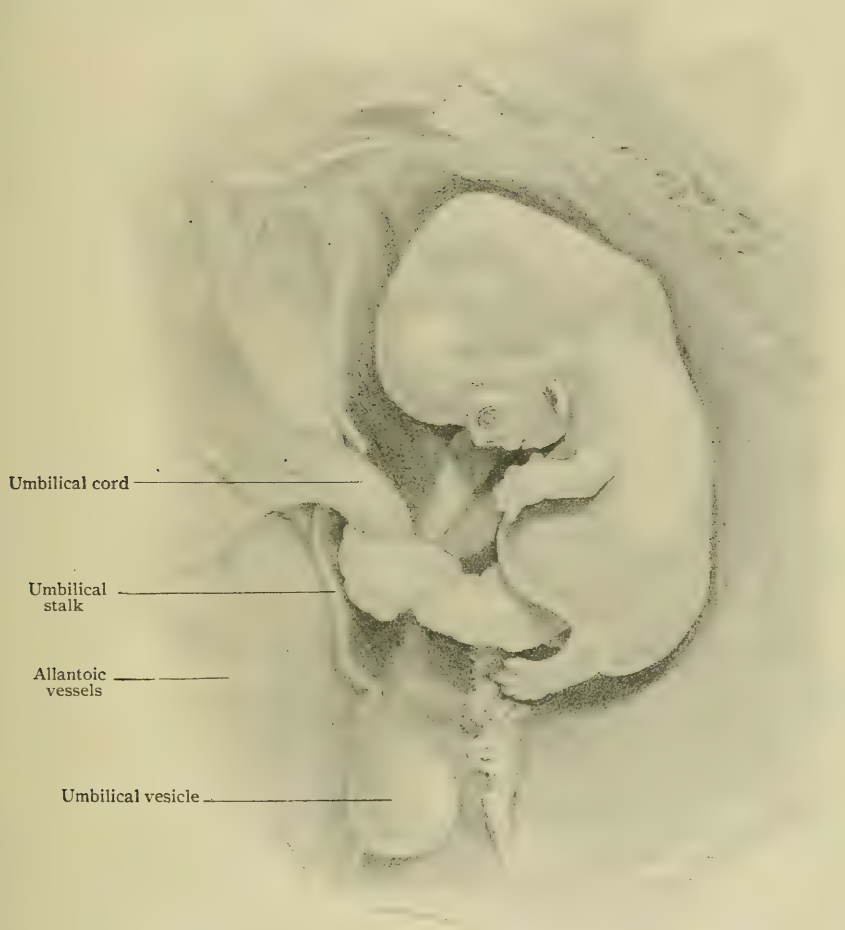


Human embryo of about thirty-five days. × 4. Amnion and chorion cut and turned aside.

ferent sexual gland, and the undifferentiated external genitals, consisting of the genital eminence and the associated genital folds and genital ridges. The external ear has assumed its characteristic form, and the eyelids appear as low folds encircling the conspicuous eye, in which the pigmentation of the ciliary region is visible. Although the face is well formed, the nose is still flat, the lips but slightly prominent, and the palate not completely closed. The rapid growth of the brain results in the disproportionate size of the head, which at this stage almost equals the trunk in bulk. It is to be noted that by the close of the second month the permanent organs are so far advanced that the subsequent growth of the fœtus is effected by the further development of parts already formed and not by the accession of new organs. The beginning of the second month marks the period of *greatest relative growth;* at the end of this month the fœtus measures about thirty millimetres in its longest dimension.

The **third month** is characterized by greater perfection of the external form, the rounded head is raised from the trunk so that a distinct neck appears, while the thorax and abdomen are less prominent ; the limbs, which are well developed with completed differentiation of the fingers and toes, provided with imperfect nails, now assume the characteristic fœtal attitude. The eyelids become united by the tenth week, remaining closed until the end of the seventh month. The cloacal opening becomes differentiated during the ninth and tenth weeks into the genito-urinary and

FIG. 79.



Human fœtus of about eight weeks. × 3½. Amnion has been cut and reflected, but still covers the umbilical vesicle and its stalk.

the anal orifice, while during the eleventh and twelfth weeks the external genital organs acquire the distinguishing peculiarities of a definite sex. The greatest length of the fœtus, measured in its natural position and excluding the limbs, at the end of the third month, is about eighty millimetres ; its weight approximates twenty grammes.

The **fourth month** witnesses augmented growth in the fœtus, which, however, resembles in its general appearance the fœtus of the preceding month. The

extra-fœtal portion of the intestinal canal, which at an earlier period passes into the umbilical cord, during the fourth month recedes within the abdomen. The differentiation of sex is still more sharply exhibited by the external organs : in the male the penis is acquiring a prepuce, and in the female the labia majora and the clitoris are becoming well developed. At the close of this period the fœtus measures approximately 150 millimetres and weighs about 120 grammes.

During the **fifth month** the first fœtal movements are usually observed. The heart and the liver are relatively of large size. The decidua capsularis fuses with the decidua vera, thereby obliterating the remains of the uterine cavity. The meconium within the intestinal canal shows traces of bile. The advent of the fine hair, the *lanugo*, first upon the forehead and the eyebrows, and somewhat later upon the scalp and some other parts of the body, represents a conspicuous advance. Likewise adipose tissue appears in places within the subcutaneous layer. The approximate length, at the end of the fifth month, is twenty-three centimetres and the average weight about 320 grammes.

The **sixth month** is characterized by complete investment of the body by lanugo and by the appearance of the *vernix caseosa*, the protecting sebaceous secretion which coats the body of the fœtus to prevent as far as possible maceration of the epidermis in the amniotic fluid. The latter now reaches the maximum quantity, being contained within the large sac of the amnion. The sixth month is distinguished by the conspicuous increase both in the size and weight of the fœtus, and is known, therefore, as the period of *greatest absolute growth*. At the close of the sixth month the fœtus measures approximately thirty-four centimetres in its longest dimension and weighs about 980 grammes.

The **seventh month** is marked by progressive changes in the various parts of the fœtus, whereby the more advanced details become pronounced in the central nervous system and digestive tract. The length of the fœtus at the close of the seventh month approximates forty centimetres and its weight about 1700 grammes.

The **eighth month** is occupied by the continued growth and general development, as part of which the fœtus acquires greater plumpness than before and a brighter hue of the integument, now entirely covered with vernix caseosa. The lanugo begins to disappear, while the scalp is plentifully supplied with hair ; the nails have reached, or project beyond, the tips of the fingers. By the close of the eighth month the fœtus has attained a length of about forty-six centimetres and a weight of about 2400 grammes.

The **ninth month** witnesses the gradual assumption of the characteristics of the child at birth, among which are the rounder contours, the extensive, although not complete, disappearance of the lanugo, except from the face, where it largely persists throughout life, the completed descent of the testicles within the scrotum, the approximation of the labia majora, the permanent separation of the eyelids, with well-developed lashes, and the presence of dark greenish meconium within the intestinal canal. The umbilicus has reached a position almost exactly in the middle of the body. The average length of the fœtus at birth is about fifty centimetres, or twenty inches ; its average weight, while included between widely varying extremes, may be assumed as approximately 3100 grammes, or 6.8 pounds. The weight of the fœtus at term is materially influenced by the age of the mother, women of about thirty-five years giving birth to the heaviest children. The weight and stature of the mother probably also affect the weight of the child. Repeated pregnancies exert a pronounced effect upon the fœtus, since the weight of the child reaches the maximum with the fifth gestation.

The purpose of the preceding pages is to present an outline of the general developmental processes leading to the differentiation and establishment of the definite body-form of the human embryo ; a more detailed account of the development of the various parts of the body is given in connection with the descriptions of the systems and the individual organs, to which the reader is referred.

THE ELEMENTARY TISSUES.

THE various parts and organs of the complex body may be resolved, in their morphological constitution, into a few component or *elementary tissues*, of which there are four principal groups,—the *epithelial*, the *connective*, the *muscular*, and the *nervous* tissues. The first two of these may be discussed at this place ; the remaining groups, the muscular and the nervous tissues, are considered most advantageously in connection with the muscular and nervous systems to which they are directly related and under which sections they will be found.

THE EPITHELIAL TISSUES.

The epithelial tissues include, primarily, the integumentary sheet of protecting cells covering the exterior of the body and the epithelium lining the digestive tube. Secondarily, they embrace the epithelial derivatives of the epidermis, such as the nails, hairs, and glands of the skin and its extensions, and the epithelial lining of the ducts and compartments of the glands formed as outgrowths from the primitive gut-tube, as well as the epithelium clothing the respiratory tract which originates as an evagination from the digestive canal.

An apparent exception to the usual origin of the epithelial tissues from either the ectoblast or the entoblast is presented by the lining of the genito-urinary tract, since all the epithelium occurring in connection with these organs, as far as the bladder, is of mesoblastic origin, and hence genetically related closely with the extensive mesoblastic group of tissues. It is to be noted in this connection that the epithelium of the bladder and of a part of the urethra is derived from outgrowths of the primary gut, and therefore is entoblastic in origin.

The primary purpose of epithelium being protection of the more delicate vascular and nervous structures lying within the subjacent connective tissue of the integument or of the mucous membrane, the protecting cells are arranged as a continuous sheet, the individual elements being united by a small amount of intercellular substance.

Epithelium contains no blood-vessels, the necessary nutrition of the tissue being maintained by the absorption of the nutritive juices which pass to the cells by way of the minute clefts within the intercellular substance. Likewise, the supply of nerve-fibres within epithelium ordinarily is scanty, although in certain localities possessing a high degree of sensibility, as the cornea or tactile surfaces, the terminations of the nerves may lie between the epithelial elements.

The epithelial tissues are frequently separated from the subjacent connective tissue by a delicate *basement membrane*, or *membrana propria ;* the latter, which may be regarded as a derivative or modification of the connective tissue, usually appears as a delicate subepithelial boundary, being particularly well marked beneath the epithelium of glands.

According to the predominating form of the component cells, the epithelial tissues are best divided into two chief groups,—*squamous* and *columnar*,—with subdivisions as shown in the following table :

VARIETIES OF EPITHELIUM.

I.—SQUAMOUS :
- *a.* Simple,—consisting of a single layer.
- *b.* Stratified,—consisting of several layers.

II.—COLUMNAR :
- *a.* Simple,—consisting of a single layer.
- *b.* Stratified,—consisting of several layers.

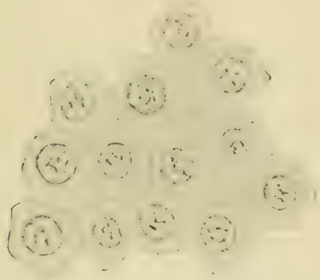
III.—MODIFIED :
- *a.* Ciliated. *b.* Goblet. *c.* Pigmented.

IV.—SPECIALIZED :
- *a.* Glandular epithelium. *b.* Neuro-epithelium.

Squamous epithelium, when occurring as a *single* layer, is composed of flattened polyhedral nucleated plates which, when viewed from the surface, present a regular mosaic, sometimes described by the terms "pavement" or "tessellated." Such arrangement of the squamous type is unusual in the human body, the lining of the alveoli of the lungs, the posterior surface of the anterior capsule of the crystalline lens, the membranous labyrinth, and a few other localities being the chief places where a single layer of squamous cells occurs.

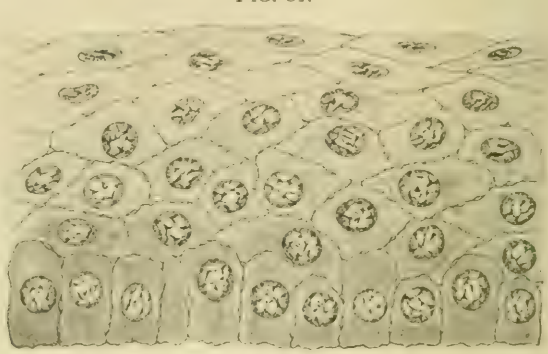
The far more usual arrangement of such cells is several superimposed layers, this constituting the important group of *stratified squamous* epithelia. When

FIG. 80.



Simple squamous epithelium from anterior capsule of crystalline lens. × 400.

FIG. 81.



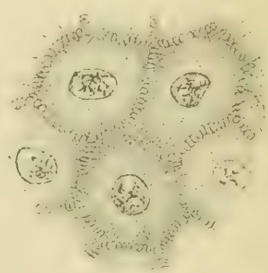
Section of stratified squamous epithelium from anterior surface of cornea. × 500.

seen in section, the deepest cells are not scaly, but irregularly columnar, resting upon the basement membrane by slightly expanded bases. The surface of the underlying connective tissue supporting this variety of epithelium is beset with minute elevations or papillæ, which serve as advantageous positions for the terminations of the blood-vessels, as well as specialized nerve-endings. Owing to the more favored nutrition of the deepest stratum, the cells next the connective tissue exhibit the greatest vitality, and often are the exclusive source of the new elements necessary

FIG. 82.

Isolated surface cells from epithelium lining the mouth. × 350.

FIG. 83.



Epithelial cells from epidermis, showing intercellular bridges. × 975.

to replace the old and effete cells which are continually being removed at the free surface; this loss is due not only to mechanical abrasion, but also to the displacement of the superficial elements by the new cells formed within the deeper layers.

Passing from the basement membrane towards the free surface, the form of the cells undergoes a radical change. The columnar type belongs to the deepest layer alone; the superimposed cells assume irregularly polyhedral forms and then gradually expand in the direction parallel to the free surface to become, finally, converted into the large, thin scales so characteristic of the superficial layers of stratified epithelium. The position of the nucleus also varies with the situation of the cells,

since within those next the basement membrane the relatively large nucleus—the nutritive organ of the cell—occupies the end nearest the subjacent connective tissue; in the middle and superficial strata, the nucleus, comparatively small in size, is placed about the centre of the cell.

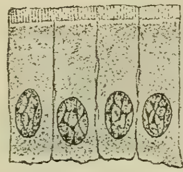
The irregularly polyhedral cells of the deep or middle strata frequently are connected by delicate processes which bridge the intervening intercellular clefts; when such elements are isolated, the delicate connecting threads are broken and the disassociated elements appear beset with minute spines, then constituting the *prickle-cells.*

In certain localities, as in the urinary bladder, the columnar cells of the deepest layer rapidly assume the scaly character of the superficial strata; such epithelium

FIG. 84.

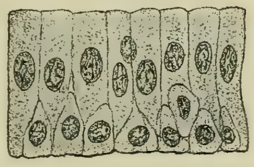
Transitional epithelium from bladder of child. × 300.

FIG. 85.



Simple columnar epithelium from intestinal mucosa. × 750.

FIG. 86.

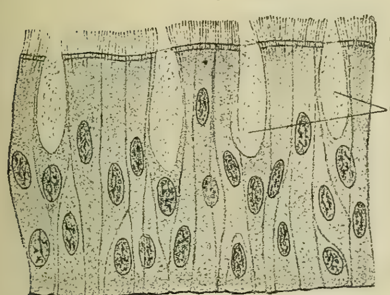


Stratified columnar epithelium from vas deferens. × 500.

possesses relatively few layers, and from the readiness with which the type of the cells changes, is often described as *transitional epithelium;* the latter cannot be regarded as a distinct variety, but only as a modification of the stratified scaly group.

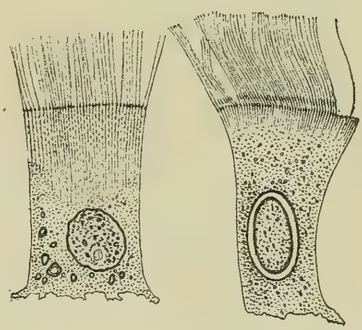
Columnar epithelium, when occurring as a single layer of cells, constitutes the *simple columnar* variety, which enjoys a much wider distribution than the corresponding squamous group, the lining of the stomach and of the intestinal tube being important examples. When the single layer of such epithelial tissues is replaced by several, as in the *stratified columnar* variety, the superficial cells alone

FIG. 87.



Stratified ciliated columnar epithelium from trachea of child. × 550.

FIG. 88.

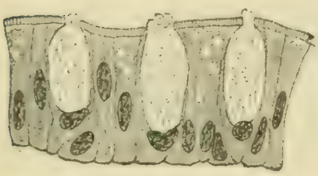


Ciliated epithelial cells. *A*, from intestine of a mollusk (*cyclas*); *B*, from nasal cavity of frog. × 750. (*Engelmann.*)

are typically columnar. The free ends of the columnar elements not infrequently present specializations in the form of a *cuticular border* or of cilia, while their ends which rest upon the basement membrane are pointed, forked, or club-shaped. The intervals thus formed by irregularities of contour are occupied by the cells of the deeper stratum next the basement membrane. Each cell is provided with a nucleus, which is situated about midway between the ends of the superficial elements and nearer the base within the deeper ones. The surface cells often contain collections of mucous secretion which distend their bodies into conspicuous chalice forms known as *goblet-cells*, which occur in great profusion in the lining of the large intestine and the respiratory mucous membrane.

Modified Epithelium.—The free surface of the epithelium in many localities, as in the trachea, the inferior and middle nasal meatuses, and the uterus, is provided with minute, hair-like vibratile processes, or *cilia*, which are produced by the specialization of the cytoplasm of the free end of the cell. The exact relations of the cilia to the cytoplasm are still matters of uncertainty, although the investigations of Engelmann and others on the ciliated epithelium of invertebrates render it probable that the hair-like processes attached to the cells of higher animals are also connected with intracellular fibrillæ, which appear as delicate striations within the superficial and more highly specialized parts of the cells. In man and the higher mammals ciliated epithelium is limited to the columnar variety. The exact number of individual cilia attached to the free surface of each cell varies, but there are usually between one and two dozen such appendages. Their length, likewise, differs with locality, those lining the epididymis being about ten times longer than those attached to the tracheal mucous membrane. When favorable conditions obtain, including a sufficient supply of moisture, oxygen, and heat, ciliary motion may continue for many hours and even days.

Fig. 89.

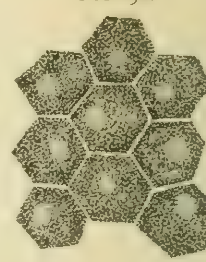


Goblet-cells from epithelium lining large intestine. × 500.

On surfaces clothed with columnar epithelium certain cells are distinguished by unusually clear cytoplasm and exceptional form and size ; these are the *goblet-cells*, the peculiar elliptical or chalice form of which results from the accumulation of the mucoid secretion elaborated within their protoplasm. When the distention becomes too great the cell ruptures in the direction of least resistance, and the secretion is poured out upon the surface of the mucous membrane as the lubricating mucus. The goblet-cells, therefore, may be regarded as unicellular glands, and represent the simplest phase in the specialization of glandular tissues.

The protoplasm of epithelial cells often becomes invaded by particles of foreign substances ; thus, granules of fatty and proteid matters are very commonly encountered, while the presence of granules of eleidin in certain cells of the epidermis characterizes the stratum granulosum. When the invading particles are colored, as when composed of melanin, the affected cells acquire a dark brown tint, and are then known as *pigmented epithelium*. Examples of such cells are seen in the retina and in the deeper cells of the epidermis in certain races.

Fig. 90.



Pigmented epithelium from human retina. × 435.

Specialized Epithelium.—Reference has already been made to goblet-cells as representing unicellular glands ; these may be regarded, therefore, as instances of a temporary specialization of epithelium into glandular tissue. When the epithelial elements become permanently modified to engage in the elaboration of secretory substances, they are recognized as *glandular epithelium*. The cells lining the ducts and the ultimate compartments of glands are modified extensions of the epithelial investment of the adjacent mucous membrane. Their form and condition depend upon the degree of specialization, varying from columnar to spherical and polyhedral, on the one hand, and upon the nature and number of the secretion particles on the other. The cells lining parts of certain glands, as those clothing the ducts of the salivary glands, or the irregular portion of the uriniferous tubules, exhibit a more or less pronounced striation ; cells presenting this peculiarity are termed *rod-epithelium*.

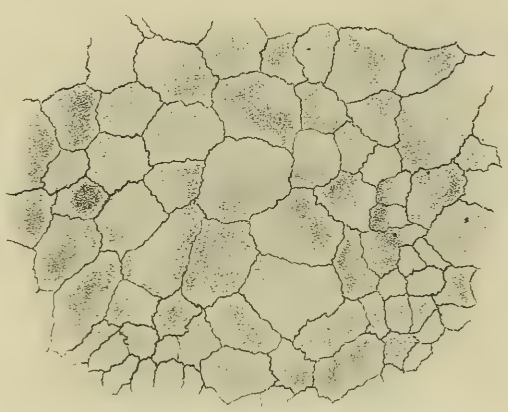
The highest, and often exceedingly complex, specializations affecting epithelial tissues are encountered in connection with the neurones supplying the organs of special sense. The epithelium in these localities is differentiated into two groups of elements,—the sustentacular and the perceptive ; to the latter the name of *neuro-epithelium* is applied. Conspicuous examples of such specialization are the rod- and cone-cells of the retina and the hair-cells of Corti's organ in the internal ear.

A more detailed description of the glandular tissues is given with the digestive tract ; that of the neuro-epithelia with the organs of special sense.

ENDOTHELIUM.

The modified mesoblastic, later connective-tissue, cells that line serous surfaces, including those of the pericardial, the pleural, and the peritoneal divisions of the body-cavity, together with those of the blood- and lymph-vessels and the lymphatic spaces throughout the body, constitute *endothelium*. These spaces, in principle, are intramesoblastic clefts and the elements forming their lining are derivatives of the great connective-tissue layer. The endothelia, therefore, belong to the connective tissues and are properly regarded as modified elements of that class ; as a matter of convenience, however, they may be considered at this place in connection with the epithelial tissues.

FIG. 91.

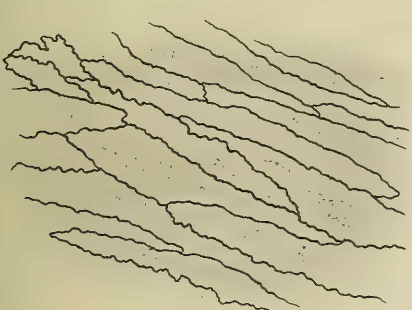


Mesothelial cells from omentum of dog. × 300. Intercellular cement-substance stained by argentic nitrate.

The most striking difference in situation between the endothelia and the epithelia is found in the fact that the former cover surfaces not communicating with the atmosphere, while the epithelial tissues clothe mucous membranes all of which are directly or indirectly continuous with the integumentary surface. A further contrast between these tissues is presented in their genetic relations with the primary blastodermic layers, since the epithelia, with the exception of those lining certain parts of the genito-urinary tracts which are derived from the mesoblast, are the transformations and outgrowths from the ectoblast and the entoblast, while the endothelia are direct modifications of the mesoblastic cells.

The young mesoblastic cells bordering the early body-cavity become differentiated into a delicate lining, the *mesothelium*, and later give rise to the characteristic plate-like elements which constitute the lining of the permanent serous sacs. The name mesothelium is sometimes retained to designate the permanent investment of the great serous cavities, as distinguished from the endothelium which clothes the vascular and other serous spaces.

FIG. 92.



Endothelial cells lining artery of dog, after silver staining. × 500.

Seen in typical preparations, as obtained from the peritoneum after treatment with argentic nitrate and subsequent staining with hæmatoxylin, the endothelial cells on surface view appear as irregularly polygonal areas mapped out by deeply tinted lines. The latter represent the silver-stained albuminous intercellular cement-substance which unites the flattened cells in a manner similar to that observed in simple squamous epithelium ; this superficial likeness is so marked that it has led to much confusion as to the proper classification of endothelium under the connective tissues. The lines of apposition are sinuous and less regular than between epithelial elements, in many cases appearing distinctly dentated. The exact form of the cells and the character of their contours, however, are not constant, since they probably depend largely upon the degree of tension to which the tissue has been subjected.

Not infrequently the intercellular substance, at points where several endothelial cells are in apposition, shows irregular, deeply colored areas after silver staining ;

these figures are described as *stigmata* or *pseudostomata*, and by some are interpreted as indications of the existence of openings leading from the serous cavity into the subjacent lymphatics. Critical examination of these areas, however, leads to the conclusion that they are largely accidental, and due to dense local accumulations of the stained intercellular materials; they are not, therefore, to be regarded as intercellular passages. True orifices or *stomata*, however, undoubtedly exist in certain serous membranes, as in the septum between the peritoneal cavity and the abdominal lymph-sac of the frog, and, possibly, the peritoneal surface of the diaphragm of mammals. The positions of these stomata are marked by a conspicuous modification in the form and arrangement of the surrounding endothelial plates, which exhibit a radial disposition about the centres occupied by the stomata. The immediate walls of the orifices are formed by smaller and more granular elements, the *guard* or *germinating cells*, the contraction and expansion of which probably modify the size of the openings.

Although the ectoblast and the entoblast are the germ layers which furnish great tracts of epithelium in the adult body, yet the mesoblast, the middle germ layer, also supplies distinct epithelial tissues. As it has been already pointed out, the epidermis, the epithelial portion of the skin, with its derivatives, is a product of the ectoblast. The epithelial lining of the mouth cavity as far back as the region of the palatine arches, and the epithelium of the anus are also of ectoblastic origin, since they are formed as in-pocketings of the outer germ layer during early embryonic life. With the exception of these areas, the epithelium lining the entire digestive tube, and that of its accessory glands, notably the liver and the pancreas, is of entoblastic origin. The same thing is true of the epithelium of the respiratory tract, since this entire tract is an outgrowth from the primitive intestine. But in the case of the uro-genital system, the epithelium there found, or most of it, is derived directly from the mesoblast. To be more specific, the Fallopian tubes (uterine tubes), uterus and vagina of the female, which have, of course, a distinct layer of epithelium on their inner surface, are formed from certain embryonic tubes known as the Müllerian ducts, which are derived from the mesoblast. The vas (ductus) deferens of the male is first represented in the embryo by a tube known as the Wolffian duct, which, with its epithelium, is also derived from the mesoblast. The sex-cells found in the sex-glands, which in the case of the male retain a distinct epithelial character, are apparently of mesoblastic origin. The ureter and part of the kidney are outgrowths from the Wolffian duct and therefore mesoblastic, while the rest of the kidney not formed in this way is also of mesoblastic origin. Hence, it is evident that distinct layers of epithelium are formed from all three germ layers, and that in this respect no peculiarity is attributable to any one of them.

THE CONNECTIVE TISSUES.

THE important group of connective substances, the most widely distributed of all tissues, is the direct product of the great mesoblastic tract; the several members of this extended family are formed by the differentiation and specialization of the intercellular substance wrought through the more or less direct agency of the mesoblastic cells. The variation in the physical characteristics of the connective tissues is due to the condition of their intercellular constituents. During the period of embryonal growth these latter are represented by gelatinous, plastic substances; a little later by the still soft, although more definitely formed, growing connective tissue, which, in turn, soon gives place to the yielding, although strong, adult areolar tissue.

Grouped as masses in which white fibrous tissue predominates, the intercellular substance presents the marked toughness and inextensibility of tendon; where, on the contrary, large quantities of yellow elastic tissue are present, extensibility is conspicuous. Further condensation of the intercellular substance produces the resistance encountered in hyaline cartilage, intermediate degrees of condensation being presented by the fibrous and elastic varieties. In those cases in which the ground-substance becomes additionally impregnated with calcareous salts, the well-known hardness of bone or dentine is attained. Notwithstanding these variations in the density of the intercellular substance, the cellular elements have undergone but little change, the connective-tissue corpuscle, the tendon-cell, the cartilage-cell, and the bone-corpuscle being morphologically identical.

FIG. 93.

Embryonal connective-tissue cells from the umbilical cord. $\times$ 500.

The principal forms in which the connective substances occur may be grouped as follows:

1. *Immature connective tissue*, as the jelly of Wharton in the umbilical cord and the tissues of embryos and of young animals.

2. *Areolar tissue*, forming the subcutaneous layer and filling intermuscular spaces, and holding in place the various organs.

3. *Dense fibro-elastic tissue*, found in the fasciæ, the sclera, the ligaments, etc. Where white fibrous tissue predominates and yellow elastic tissue is practically wanting, structures of the character of tendon or of the cornea are produced; where, on the other hand, elastic tissue is in excess of fibrous tissue, highly extensible structures, as the ligamentum nuchæ or the ligamenta subflava, result.

4. *Cartilage*, fibrous, elastic, and hyaline varieties.

5. *Bone* and *dentine*, in which impregnation of lime salts contributes characteristic hardness.

6. *Reticulated connective tissue*, occurring as the supporting framework in the lymphatic tissues, and as the interstitial reticulum of many organs.

7. *Adipose tissue*.

The Cells of Connective Tissue.—The cellular elements of the connective

tissues are usually described as of two kinds, the *fixed* or connective-tissue cells proper, and the migratory or *wandering* cells. The latter, while frequently included among the elements of these tissues, are usually only migratory leucocytes which temporarily occupy the lymphatic clefts within the connective substance.

FIG. 94.

Young connective-tissue cells from subcutaneous tissue of cat embryo. × 590.

FIG. 95.

Granule-cells (mast-cells) from submucous tissue of mouth. × 1000 v, v, sections of blood-vessels.

The *typical connective-tissue cell*, in its younger condition, possesses a flattened, plate-like body from which branched processes extend. With the completed growth of the tissue, the expanded, often irregularly stellate, element contracts to the inconspicuous spindle cell commonly observed in adult areolar tissue.

FIG. 96.

Section of subcutaneous tissue, showing the usual constituents of areolar tissue. × 300.

Granule-cells are additional elements occasionally encountered in connective tissues. They are irregularly spherical in form and are distinguished by conspicuous granules within their protoplasm possessing a strong affinity for dahlia and other basic aniline stains. They include the *plasma-cells* of Waldeyer and the *mast-cells* of Ehrlich.

Pigment-Cells.—The fixed cells sometimes contain accumulations of dark particles within their cytoplasm, the elements then appearing as large, irregularly branched *pigment-cells;* these are conspicuous in man within the choroid, the iris, and certain parts of the pia mater. The nucleus usually remains uninvaded, and hence appears as a lighter area within the dark brown, or almost black, cell-body.

The **Intercellular Constituents** of the connective substances occur in three forms,—*fibrous tissue*, *reticular tissue*, and *elastic tissue*.

Fibrous tissue consists morphologically of varying bundles of silky fibrils of

such fineness that they possess no appreciable width. The fibrils are united by and embedded within a semifluid *ground-substance*, which may be present in such meagre amount that it suffices only to hold together the fibrillæ, or, on the other hand, it may constitute a large part of the entire intercellular tissue, as in the matrix of hya-

FIG. 97.

Pigmented connective-tissue cells from choroid. × 400.

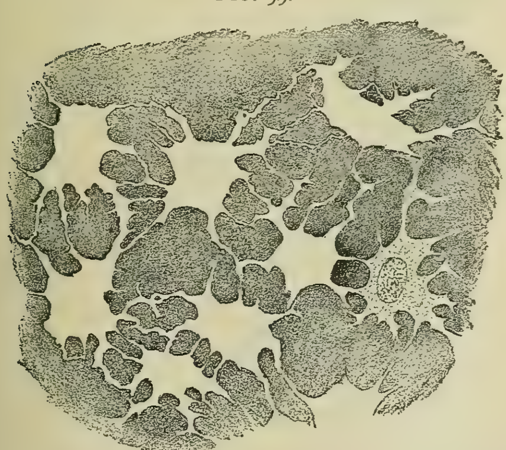
FIG. 98.

Surface view of portion of omentum. × 130. Fibrous and elastic tissue are arranged as a fenestrated membrane; the nuclei belong to the connective-tissue and the endothelial cells.

line cartilage. Depending upon the disposition of the bundles, fibrous tissue occurs in two principal varieties,—*areolar* and *dense* connective tissue.

The fibrous tissue of the areolar group is arranged in delicate wavy bundles which are loosely and irregularly interwoven, as seen in the subcutaneous layer, the intervening clefts being largely occupied by the ground-substance. In the denser connective tissues the fibrous tissue is disposed with greater regularity, either as closely packed, parallel bundles, as in tendon and aponeuroses, or as intimately felted, less regularly arranged, bands forming extended sheets, as in fasciæ, the cornea, and the dura mater. The ground-substance uniting the fibrillæ of dense connective tissues often contains a system of definite interfascicular *lymph-spaces*, which, in suitably stained preparations, appear as irregularly stellate clefts that form, by union of their ramifications, a continuous net-work of channels for the conveyance of the tissue-juices throughout the dense connective substances ; in non-vascular structures, as the cornea and the denser parts of bone, these systems of intercommunicating lymph-spaces serve to convey the nutritive substances to the connective-tissue cells which lie within these clefts. Fibrous tissue yields gelatin on boiling in water, and is not digested by pancreatin ; on the addition of acetic acid this tissue becomes swollen and transparent, the individual fibrillæ being no longer visible.

FIG. 99.

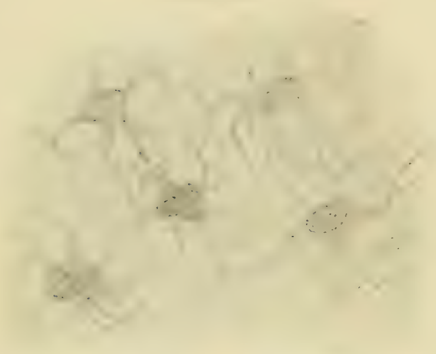


Cell-spaces of dense connective tissue from cornea of calf; the surrounding ground-substance has been stained with argentic nitrate. × 525.

Reticular Tissue.—The investigations of Mall have emphasized the presence of a modified form of fibrous tissue in many localities, especially in organs rich in lymphoid cells. This variety of intercellular substance, known as *reticular tissue* or *reticulum*, consists of very fine fibrillæ, either isolated or associated

as small bundles, which unite in all planes to form delicate net-works of great intricacy. In lymphatic tissues, where the reticulum reaches a typical development, the mesh-work contains the characteristic lymphoid elements and, in addition, supports the superimposed stellate connective-tissue cells which formerly were erroneously regarded as integral parts of the fibrillar net-work. Reticular tissue, associated with fibrous and elastic tissue, is also present in many other organs, as the liver, kidney, and lung. This modification of fibrous tissue differs from the more robustly developed form in the absence of the ground-substance and not yielding gelatin upon boiling in water (Mall); like fibrous tissue, the reticulum resists pancreatic digestion.

FIG. 100.



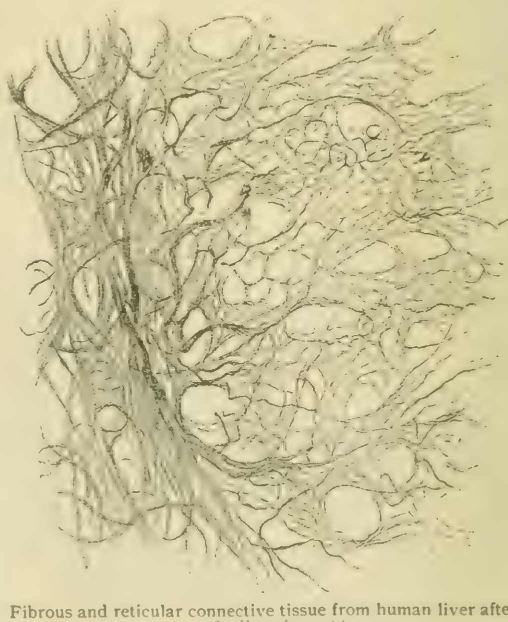
Connective-tissue cells from cornea of calf which occupy cell-spaces similar to those shown in preceding figure. × 525.

The **development** of fibrous tissue has been a subject of much discussion regarding which authorities are still far from accord. Two distinct views are held at the present time ; according to the one, the fibres appear within the originally homogeneous intercellular matrix of the early embryonal connective tissue without the direct participation of the cells, the fibres being formed as the result of a process somewhat resembling coagulation. This conception of the formation of the fibres of connective tissue, known as the *indirect mode*, is held to account for the earliest production of the fibrils in embryonic tissue.

The other view, held by Flemming, Reinke, and others, attributes an active participation of the young connective tissue cell, the peripheral zone of its protoplasm, known as exoplasm, being directly transformed into fibrillæ. In consideration of the careful observations of Flemming, it is now widely believed that the method of formation of the fibres of connective tissue *directly* from the exoplasm of young connective tissue cells is the usual one.

It is highly probable that the connective tissue cells are concerned in the production of the fibrous tissue, since these elements become much smaller as the formation of the fibrous tissue advances.

FIG. 101.

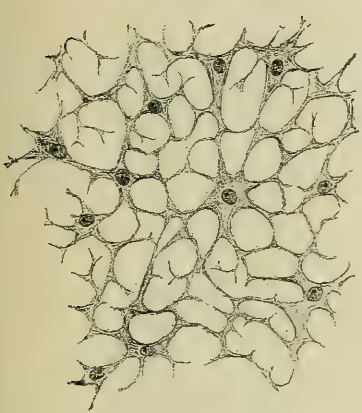


Fibrous and reticular connective tissue from human liver after pancreatic digestion. × 230.

Elastic tissue usually occurs as a net-work of highly refracting, homogeneous fibres lying among the bundles of fibrous tissue. The individual fibres are much thicker than the fibrillæ of fibrous tissue and, although differing in width, maintain a constant diameter until augmented by fusion with others. When disassociated, as in teased preparations, the elastic fibres assume a highly characteristic form, being wavy, bowed, or coiled. The proportion of elastic tissue in connective substances is, ordinarily, small ; in certain localities, however, as the ligamenta subflava of man, or especially the ligamentum nuchæ of the lower mammals, almost the entire structure consists of bundles of robust fibres of elastic

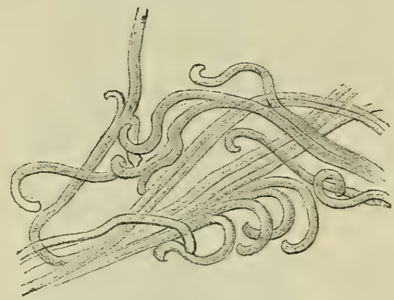
tissue held together by a small amount of intervening fibrous tissue. In transverse section of such ligaments (Fig. 104), the individual elastic fibres appear as minute polygonal areas separated by the fibrous fibrillæ and the associated connective-tissue cells. Within the walls of the large blood-vessels the elastic tissue is arranged as membranous expansions containing numerous openings of varying size : these *fenestrated membranes*, as they are called, are probably formed by the junction and fusion of broad ribbon-like elastic fibres. Elastic tissue yields elastin upon boiling in water, and disappears upon being subjected to pancreatic digestion, thus differing from fibrous and reticular tissue; by taking advantage of the especial affinity that elastic tissue possesses for certain stains, as orceïn, a much wider and more generous distribution of elastic tissue has been established than was formerly appreciated.

FIG. 102.



Reticular connective tissue from lymph-node. × 350. The cells lie upon the fibrous tissue at the points of intersection.

FIG. 103.



Portions of isolated elastic fibres from ligamentum nuchæ of ox. × 375.

The **development** of elastic tissue has shared the uncertainty surrounding the mode of production of fibrous tissue, since here, as there, two opposed views have been held,—one of a cellular and one of an independent origin. According to the view of an *independent origin*, the older one, the elastic fibres first appear as rows of minute beads in the intercellular matrix. These linearly disposed beads gradually fuse, thus producing the primary elastic fibres. According to the view of an *intracellular origin*, the one less generally accepted, the elastic fibres are derived directly from the exoplasm of the young connective tissue cells, as in the case of the white fibrils.

FIG. 104.

Transverse section of ligamentum nuchæ of ox. × 450.

The density of connective substances depends upon the amount and arrangement of the fibrous tissue ; the extensibility is determined by the proportion of elastic tissue present. When the former occurs in well-defined bundles, felted together into interlacing lamellæ, dense and resistant structures result, as fasciæ, the cornea, etc.; in such structures the cement- or ground-substance within the interfascicular clefts usually contains the lymph-spaces occupied by the connective-tissue cells.

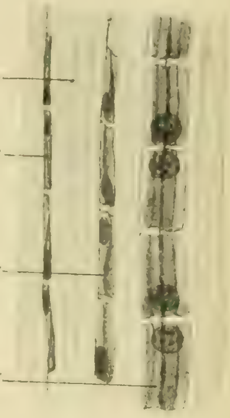
Tendon.—Tendon consists of dense connective tissue composed almost entirely of white fibrous tissue arranged in parallel bundles. The individual fibrillæ

of the fibrous tissue, held together by cement-substance, are associated as comparatively large *primary bundles*, which in turn are united by interfascicular fibrous

FIG. 105.

Longitudinal section of tendon from young subject; the tendon-cells are seen in profile between the bundles of fibrous tissue. × 300.

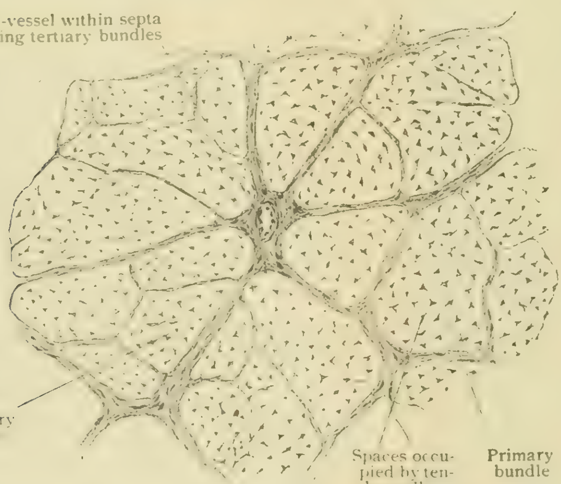
FIG. 106.



Tendon-bundles from tail of mouse, showing different views of the cells. × 300.

substance and grouped into *secondary bundles*. The former, invested by a delicate areolar sheath and partially covered by plate-like cells, are held together by the septal extensions of the general connective-tissue envelope which surrounds the entire tendon; the larger septa support the interfascicular blood-vessels and the lymphatics.

FIG. 107.



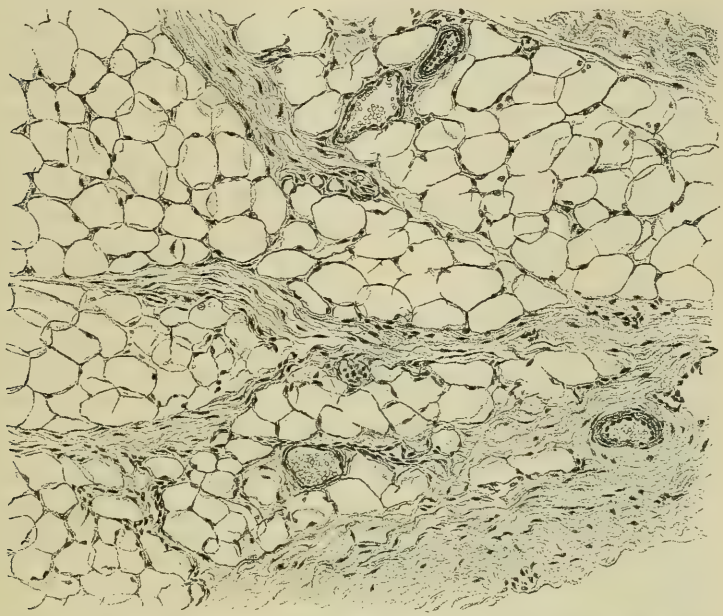
Transverse section of a tendon, showing grouping of primary, secondary, and tertiary bundles of tendon-tissue. × 85.

The flattened connective-tissue elements, here known as the *tendon-cells*, occur in rows within the clefts between the primary bundles, upon and between which the thin, plate-like bodies and wings of the tendon-cells expand. Seen from the surface, these cells appear as nucleated quadrate bodies (Fig. 106); viewed in longitudinal profile, the tendon-cells present narrow rectangular areas, while, when seen in transverse section, the same elements appear as stellate bodies, the extended limbs of which, often stretching in several planes, represent sections of the wing-plates.

Examined in cross-section (Fig. 107), the cut ends of the primary tendon-bundles appear as light irregular polygonal areas, which, under high amplification, at

times exhibit a delicate stippling due to the transversely sectioned fibrillæ. The interfascicular clefts frequently are represented, in such preparations, by stellate figures in which the sections of the tendon-cells, lying upon the primary bundles, can be distinguished ; the remaining portion of the stellate cleft is occupied by the

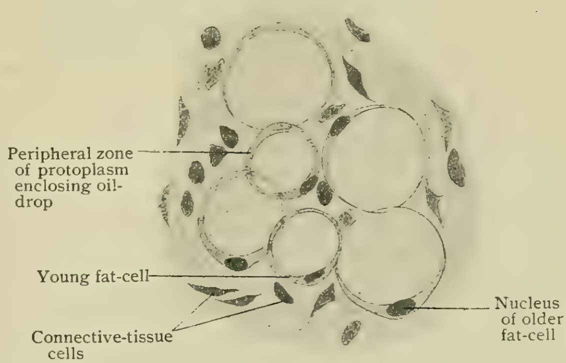
FIG. 108.



Adipose tissue from omentum. × 160. The fat-cells are arranged as groups between the bundles of connective tissue.

coagulated and stained interfascicular cement-substance. The larger divisions of the tendon, composed of the groups of secondary bundles, are separated by the septa prolonged inward from the general sheath investing the entire tendon. Tendon is composed almost exclusively of fibrous tissue, elastic fibres being practically absent.

FIG. 109.



Young fat-cells from subcutaneous tissue. × 550.

Adipose Tissue. — The fatty material contained within the body is to a large extent enclosed within connective-tissue cells in various localities ; these modified elements are known as *fat-cells*, which, together with the areolar tissue connecting the cells and supporting the rich supply of blood-vessels, constitute the adipose tissue.

The distribution of adipose tissue includes almost all parts of the body, although accumulations of fat are especially conspicuous in certain localities. Among the latter are the subcutaneous areolar tissue, the marrow of bones, the mesentery and the omentum, the areolar tissue surrounding the kidney, the vicinity of the joints, and the subpericardial tissue of the heart. On the other hand, in a few situations, including the subcutaneous areolar tissue of the eyelids, the penis and the labia minora, the lungs, except near their roots, and the interior of the cranium, adipose

tissue does not occur even when developed to excess in other parts. As ordinarily seen, adipose tissue is of a light straw color and often presents a granular texture due to the groups of fat-cells within the supporting areolar tissue.

Examined microscopically in localities where the fat-cells are not crowded, but occur in a single stratum and hence retain their individual form, adipose tissue is seen to be made up of relatively large, clear, spherical sacs held together by delicate areolar tissue. Unless treated with some stain, as osmic acid, Sudan III. or quinoline-blue, possessing an especial affinity for fat, the oily contents of the cells appear transparent and uncolored, and apparently occupy the entire cell-body. Critical study of the fat-cell, however, demonstrates the presence of an extremely thin enveloping layer of protoplasm, a local thickening on one side of the sac marking the position of the displaced and compressed nucleus (Fig. 109).

Fat-cells occur usually in groups, supported and held together by highly vascular connective tissue. In localities possessing considerable masses of fat, as beneath the scalp and the skin, the cells are grouped into lobules which appear as yellow granules to the unaided eye ; in such localities the typical spherical shape of the individual fat-cells is modified to a polyhedral form as the result of the mutual pressure of the closely packed vesicles.

In connective-tissue elements about to become fat-cells, isolated minute oil-drops first appear within the protoplasm ; these increase in size, coalesce, and gradually encroach upon the cytoplasm until the latter is reduced to a thin, almost inappreciable, envelope, which invests the huge distending oil-drop. The nucleus, likewise, is displaced towards the periphery, where it appears in profile as an inconspicuous crescent embedded within the protoplasmic zone. After the disappearance of the fatty matters, as during starvation, the majority of fat-cells are capable of resuming the usual appearance and properties of connective-tissue corpuscles ; certain groups of cells, the *fat-organs* of Toldt, however, exhibit an especial tendency to form adipose tissue, and hence only under exceptional conditions part with their oily contents.

CARTILAGE.

Cartilage includes a class of connective tissue in which the intercellular substance undergoes increasing condensation until, as in the hyaline variety, the intercellular matrix appears homogeneous, the constituent fibres being so closely blended that the fibrous structure is ordinarily no longer appreciable.

Depending upon the differences presented by the intercellular matrix, three varieties of cartilage are recognized,—*hyaline*, *elastic*, and *fibrous*. Considered in relation to the denser connective tissues, the description of fibrous cartilage, which differs but little from white fibrous tissue, should next follow ; since, however, the term "cartilage" is usually applied to the hyaline variety, the latter will first claim attention.

Hyaline cartilage, or gristle (Fig. 110), enjoys a wide distribution, forming the articular surfaces of the bones, the costal cartilages, the larger cartilages of the larynx and the cartilaginous plates of the trachea and bronchi, the cartilages of the nose and part of the Eustachian tube. In the embryo the entire skeleton, with the exception of part of the skull, is mapped out by primary hyaline cartilage.

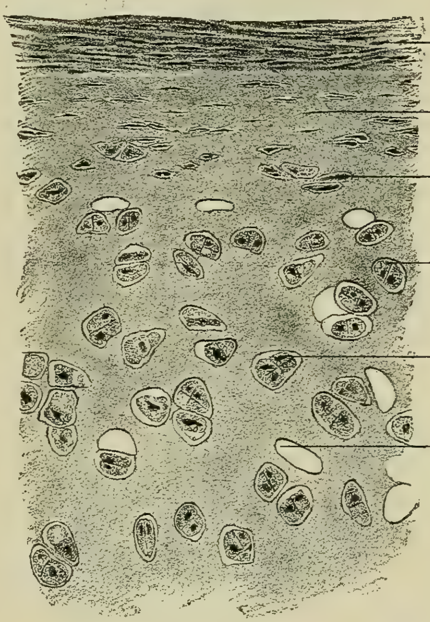
The apparently homogeneous *matrix* of hyaline cartilage, after appropriate treatment, is resolvable into bundles of fibrous tissue ; ordinarily, however, these are so closely united and blended by the cementing ground-substance that the presence of the component fibrils is not evident.

The *cartilage-cells*, as the connective-tissue elements which lie embedded within the hyaline matrix are called, are irregularly oval or spherical, nucleated bodies. They occupy more or less completely the interfascicular clefts, or *lacunæ*, within which they are lodged. In adult tissue usually two or more cells share the same compartment, the group representing the descendants from the original occupant of the space. The matrix immediately surrounding the lacunæ is specialized as a layer of different density, and is often described as a *capsule* ; a further differentiation of the ground-substance is presented by the more recently formed matrix, which

often stains with greater intensity, thereby producing the appearances known as the *cell-areas.* The lacunæ of hyaline cartilage are homologous with the lymph-spaces of other dense forms of connective tissue ; although canals establishing communication between the adjacent lacunæ are not demonstrable in the tissues of the higher vertebrates, it is not improbable that minute interfascicular passages exist which facilitate the access of nutritive fluids to the cells enclosed within the lacunæ.

The free surface of cartilage is covered by an envelope of dense connective tissue, the *perichondrium ;* the latter consists of an external *fibrous layer* of dense fibro-elastic tissue and an inner looser stratum or *chondrogenetic layer*, containing numerous connective-tissue cells. These are arranged in rows parallel to the surface of the cartilage and, during the growth of the tissue, gradually assume the characteristics of the cartilage-cells, being at first spindle-shaped and later ovoid and spherical. The young cartilage-cells thus formed become gradually separated by more extensive tracts of the newly deposited intercellular matrix ; as the groups of cells originating from the division of the original occupant of the lacuna recede from the perichondrial surface, they lose their primary parallel disposition and become irregularly arranged and still further separated. Those portions of the ground-substance most remote from the perichondrium at times appear granular, this feature being intensified when, as in aged subjects, a deposition of calcareous matter takes place in these situations.

FIG. 110.



Transverse section of peripheral portion of costal cartilage, × 250.

In *articular cartilage* the superficial zone contains sparsely distributed groups of small cells arranged parallel to the free surface ; in the deeper strata these groups are replaced by elongated rows of larger elements lying perpendicular to the articular surface. This columnar disposition of the cartilage-cells is particularly evident towards the underlying zone of calcified matrix.

The *blood-vessels* of normal cartilage are usually limited to the periphery, within the perichondrium or the associated synovial membranes ; the nutrition of the cartilage is maintained by imbibition of the fluids through the matrix into lacunæ, the existence of minute interfascicular canals being not impossible. In the thicker masses of the tissue, as in the cartilages of the ribs, nutrient canals exist in those portions most remote from the perichondrium ; these spaces contain a small amount of areolar tissue supporting the blood-vessels, which are, however, limited to the channels, the nutrition of the cartilage tissue being effected here, as at the periphery, by absorption through the matrix.

Nerves have never been demonstrated within the cartilages, which fact explains the conspicuous insensibility of these tissues so well adapted to the friction, concussion, and compression incident to their function.

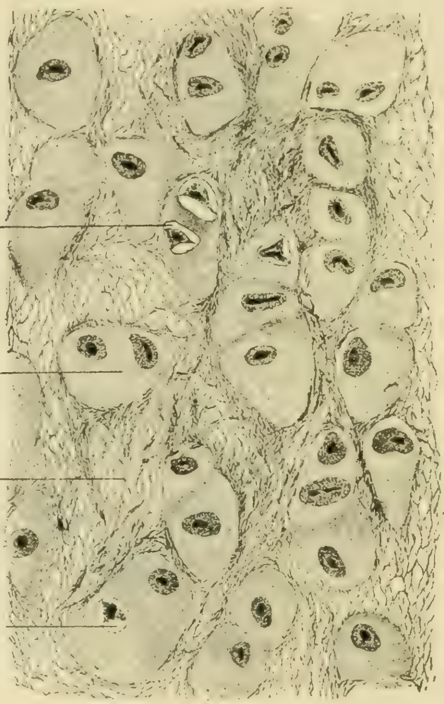
Elastic cartilage, called also *yellow elastic* or *reticular* cartilage (Fig. 111), has a limited distribution, occurring principally in the cartilages of the external ear, part of the Eustachian tube, the epiglottis, the cartilages of Wrisberg and of Santorini, and part of the arytenoid cartilages of the larynx. In its physical properties this variety differs markedly from hyaline cartilage, as it is dull yellowish in color

and pliable and tough in consistence, in contrast to the bluish opalescent tint and comparative brittleness of the hyaline variety.

The characteristic feature of the structure of the elastic cartilage is the presence of elastic fibres within the intercellular matrix. The cell-nests are immediately surrounded by limited areas of hyaline intercellular substance corresponding to the matrix of hyaline cartilage. The matrix intervening between these homogeneous fields, however, is penetrated by delicate, often intricate, net-works of elastic fibres extending in all directions. The connective-tissue cells lie within the lacunæ, in the hyaline areas, and closely resemble the elements of hyaline cartilage. Elastic cartilage possesses a perichondrium of the usual description.

Fibrous cartilage, or *fibro-cartilage* (Fig. 112), as the fibrous variety is usually designated, is found in comparatively few localities, the marginal plates and the interarticular disks of certain joints, the symphyses, the intervertebral disks, sesamoid cartilages, and the lining of bony grooves for tendons being its chief representatives.

FIG. 111.



Section of elastic cartilage from the epiglottis. × 450.

In its physical properties this tissue resembles both fibrous tissue and cartilage, possessing the flexibility and toughness of the former combined with the firmness and elasticity of the latter. A proper perichondrium is wanting.

In structure fibro-cartilage closely resembles dense fibrous tissue, since its principal constituent is the generally parallel wavy bundles of fibrous connective tissue ; among the latter lie small, irregularly disposed oval or circular areas of hyaline matrix which surround the cartilage-cells, singly or in groups. The number of cells and the proportion of fibrous matrix differ in various localities.

The **development** of cartilage proceeds from the mesoblast, the cells of which undergo proliferation and, forming compact groups, become the embryonal cartilage-cells ; at first the latter lie in close apposition, since the matrix is wanting. During the later stages, when the masses of embryonal cartilage map out the subsequent skeletal segments, the cells are separated by a small amount of homogeneous matrix formed through the influence of these elements.

Cartilage grows in two ways : (*a*) by the expansion produced by the *interstitial growth* effected by the formation of new cells and the associated matrix, and (*b*) by the addition of the new tissue developed by *perichondrial growth* at the periphery of the cartilage from the chondrogenetic layer. The latter mode continues throughout the period of growth, and includes the direct conversion of the connective-tissue cells of the perichondrium into the cartilage elements, and the accompanying formation of new matrix.

FIG. 112.

Section of fibrous cartilage from intervertebral disk. × 225.

The development of the elastic fibres within the elastic cartilage is secondary, the matrix during the early stages of growth being hyaline. The elastic tissue first appears in the form of minute granules, which later fuse and become the elastic fibres ; this change first appears in the vicinity of the cartilage-cells, the elastic reticulum subsequently invading the more remote portions of the matrix. In the development of the fibro-cartilage, the fibres appear coincidently with the limited pericellular areas of hyaline substance.

CHEMICAL COMPOSITION OF THE CONNECTIVE SUBSTANCES.

Connective Tissue.—The fibrils of white fibrous connective tissue consist of a substance known as *collagen*. The interfibrillar ground-substance contains mainly *mucoid* and the albuminous materials, serum globulin and serum albumin. *Gelatin* is the hydrate of collagen, and is obtained by boiling fibrous tissue with water, when the gelatin separates like a jelly on cooling. In the case of the **yellow elastic fibres,** *elastin* is found in place of collagen. In **reticular tissue** *reticulin* is found. The latter substance contains phosphorus. These substances, namely, collagen with its hydrate gelatin, elastin and perhaps reticulin, are among those known as albuminoids, which are closely related to the true albumins, yet differ in some important respects. The albuminoids, for the most part, contain less carbon and more oxygen than the albumins proper.

Cartilage.—The fibres which are found in the matrix of fibro-cartilage and elastic cartilage are respectively composed of collagen and of elastin, just as they are in the corresponding connective tissues.

According to His, the chemical composition of human cartilage is as follows :

	Costal cartilage.		Articular cartilage.	
Water	67.67		73.59	
Solids	32.33		26.41	
Organic matter		30.13		24.87
Mineral salts		2.20		1.54

In the mineral salts there is about 45 per cent. of sodium sulphate. A somewhat smaller percentage of potassium sulphate, and smaller amounts of the phosphates of sodium, calcium and magnesium, as well as of sodium chloride, are present.

Adipose Tissue.—The fats in the animal body are mainly the triglycerides of stearic, palmitic and oleic acid. There is found in man a comparatively large amount of olein. Small quantities of lecithin, cholesterin and free fatty acids are also found in fat tissue.

BONE OR OSSEOUS TISSUE.

In the higher vertebrates, osseous tissue forms the bony framework, or skeleton, which gives attachment and support to the soft parts, affords protection to the more or less completely surrounded delicate organs, supplies the passive levers for the exercise of muscular action, insures stability, and maintains the definite form of the animal.

In addition to contributing the individual bones composing the principal, and in man the only, framework, or *entoskeleton*, osseous tissue occurs in the lower vertebrates associated with the integument as an *exoskeleton*. Representatives of the latter are seen in the bony plates present in the skin of certain ganoid fishes, the dermal plates of crocodiles, the dorsal and ventral shields of turtles, or the dermal armor of the armadillo. Osseous tissue also exists within various organs in certain animals and then constitutes the *splanchnoskeleton*. Examples of the latter are furnished by the bony plates encountered in the sclerotic coat of the eyes of birds, in the diaphragmatic muscle of the camel, in the tongue of certain birds, in the heart of ruminants, in the nose, as the snout-bones of the hog, in the respiratory organs, as the laryngeal, tracheal, and bronchial bones of birds, and in the genital organs, as the penile bone of carnivorous and certain other mammals.

True osseous tissue does not occur outside the vertebrates. Many invertebrate animals possess a skeletal framework, usually external but in some cases internal. Such a framework, however, consists of calcareous incrustations, hardened excretions or concretions composed principally of calcium carbonate and of silicious structures. These earthy or mineral hard parts of invertebrates are structureless deposits, so differing materially from the bone tissue of the higher vertebrates as well in structure as in chemical composition. Sometimes a deposit of calcareous material occurs in adult cartilage, a process entirely distinct from the formation of bone tissue. Familiar examples of such calcification are seen in the costal and some of the laryngeal cartilages.

Chemical Composition.—Bone is a dense form of connective tissue, the matrix of which is impregnated with lime salts ; it consists, therefore, of two parts, an *animal* and an *earthy* portion, the former giving toughness and the latter hardness to the osseous tissue.

The animal or organic part of bone may be removed by calcination, leaving the inorganic constituents undisturbed. If a bone be heated in a flame with free access of air, the animal matter at first becomes charred and the bone black ; continued combustion entirely removes the organic materials, the earthy portion alone remaining. After such treatment, while retaining its general form, the bone is fragile and easily crushed, and has suffered a loss of one-third of its weight, due to the destruction and elimination of the animal constituents. The latter, evidently, constitute one-third and the mineral matters two-thirds of the bone. The inorganic constituents include a large amount of calcium phosphate, much less calcium carbonate, with small proportions of calcium fluoride and chloride, and of the salts of magnesium and sodium.

The animal portion of the bone, on the other hand, may be separated from the inorganic salts by the action of dilute hydrochloric acid, which dissolves out the earthly constitutents ; after such treatment the bone, although retaining perfectly its form and details, is tough and flexible, a decalcified rib or fibula being readily tied into a knot. The animal constituents of bone yield gelatin upon prolonged boiling in water, therein resembling fibrous connective tissue.

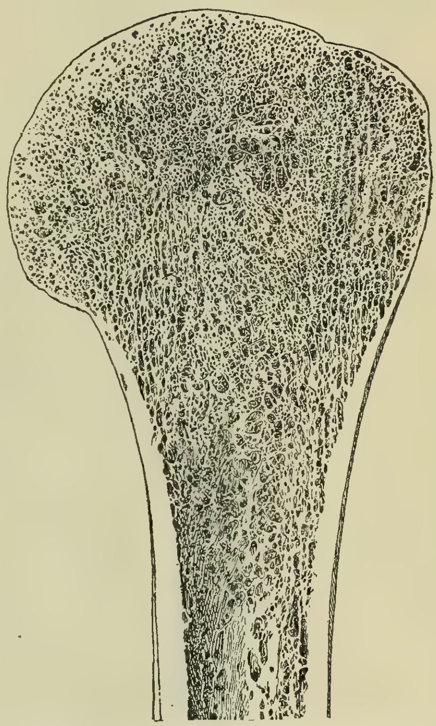
The composition of bone, according to Berzelius, is as follows :

ORGANIC MATTER	Gelatin and blood-vessels,	33.30
INORGANIC MATTER	Calcium phosphate,	51.04
	Calcium carbonate,	11.30
	Calcium fluoride,	2.00
	Magnesium phosphate,	1.16
	Sodium oxide and sodium chloride,	1.20
		100.00

Physical Properties.—Rauber has shown that a five-millimetre cube of compact bone of an ox when calcined will resist pressure up to 298 pounds; when decalcified up to 136 pounds; under normal conditions up to 852 pounds, the pressure being applied in the line of the lamellæ.

It results from its composition that while bone is very hard and resistant to pressure, it is also somewhat flexible, elastic, and capable of withstanding a tearing strain. It is remarkable that in many substances the power to resist a crushing strain is very different from that of resisting a tearing one. Thus, cast iron is more than five times as resistant to the former strain as to the latter, and wrought iron is nearly twice as resistant to the latter as to the former. Neither of these materials, therefore, is well fitted to resist both strains, since a much greater quantity must be used than would be needed were either material to be exposed only to the strain it is best able to withstand. Bone, however, has the property of resisting both strains with approximately equal facility, its tearing limit being to its crushing limit about as 3 is to 4. This has the advantage that strength need not be obtained by great increase of weight, consequently the plan of bone structure combines lightness and strength.

FIG. 113.



Section of upper end of humerus, showing the external layer of compact bone surrounding the medullary cavity below and the spongy bone above.

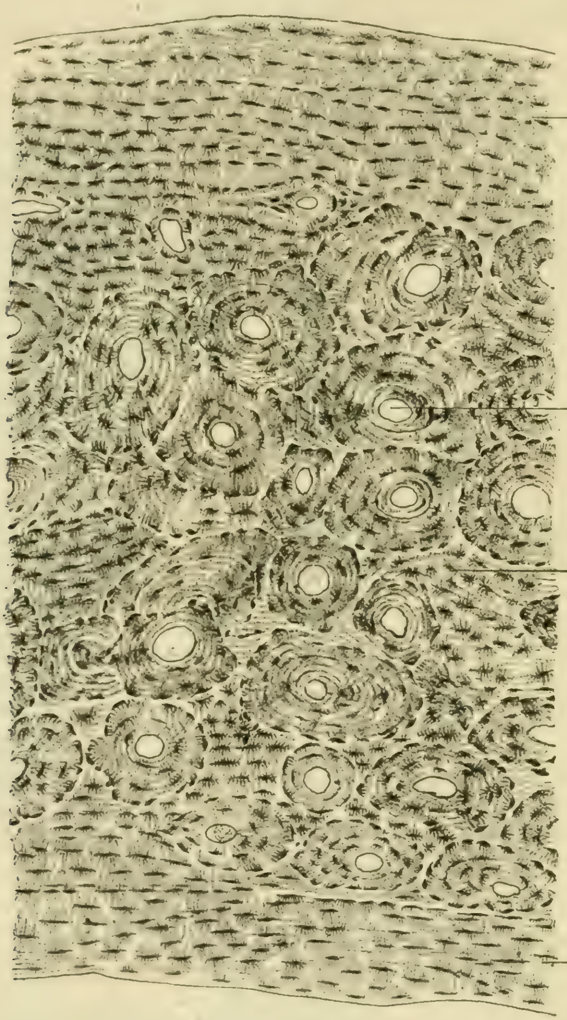
Structure of Bone. — On sawing through a bone from which the marrow and other soft parts have been removed by maceration and boiling, the osseous tissue is seen (Fig. 113) to be arranged as a peripheral zone of *compact* bone enclosing a variable amount of *spongy* or *cancellated* bone. In the typical long bones, as the humerus or femur, the compact tissue almost exclusively forms the tubular shaft enclosing the large marrow-cavity, the cancellated tissue occupying the expanded extremities, where, with the exception of a narrow superficial stratum of compact bone, it constitutes the entire framework; the clefts between the lamellæ of the spongy bone are direct extensions of the general medullary cavity and are filled with marrow-tissue. In the flat bones (Fig. 116), as those of the skull, the compact substance consists of an outer and inner plate, or *tables*, enclosing between them the cancellated tissue, or *diploë*, as this spongy bone is often termed. Short and irregular bones are made up of an inner mass of spongy bone covered by an external shell of compact substance which often presents local thickenings in order to insure additional strength where most needed.

The **cancellated bone** consists of delicate bars and lamellæ which unite to form an intricate reticulum of osseous tissue well calculated to insure considerable strength without undue weight; in many positions, conspicuously in the neck of the femur (Fig. 374), the more robust lamellæ are disposed in a definite manner with a view of meeting the greatest strains of pressure and of tension.

Although composed of the same structural elements, compact and spongy bone differ in their histological details in consequence of the secondary modifications which take place during the conversion of the spongy bone, the original form, into the compact substance. To obtain the classic picture of osseous tissue, in order to study its general arrangement in the most typical form, it is desirable to examine thin ground sections of the compact substance cut at right angles to the axis of a long bone which has been macerated and dried, and in which the spaces contain air.

The **compact bone** in such preparations, when examined under low amplification (Fig. 114), is seen to be composed of osseous layers arranged as three chief groups: (*a*) the *circumferential lamellæ*, which extend parallel to the external and internal surfaces of the compact bone; (*b*) the *Haversian lamellæ*, which are disposed concentrically and form conspicuous annular groups, the Haversian systems, enclosing the Haversian canals; and (*c*) the *interstitial* or *ground lamellæ*, which constitute the intervening more or less irregularly arranged bony layers filling up the spaces between the Haversian systems and the peripheral strata.

FIG. 114.



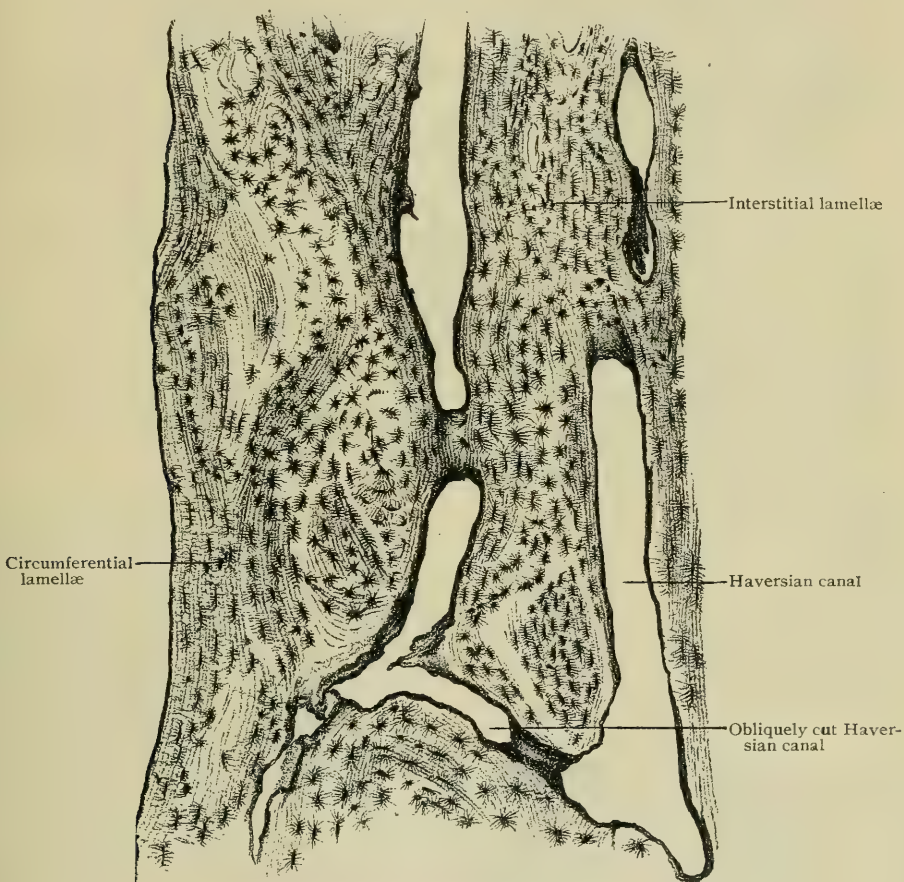
Transverse section of compact bone (metatarsal); the section has been ground and dried, hence the lacunæ are filled with air. × 85.

Each **Haversian system** consists of the concentrically disposed lamellæ and the centrally situated channel, or *Haversian canal*, enclosing the ramifications of the medullary blood-vessels and associated marrow-tissue. Between the annularly arranged lamellæ are seen small spindle-shaped or oval spaces, the *lacunæ*, about .02 millimetre long, .01 millimetre wide, and .006 millimetre thick, from which extend minute radiating channels, the *canaliculi*, establishing communication between the adjacent lacunæ of the same Haversian system. The lacunæ and the canaliculi constitute an intercommunicating net-work of lymph-spaces similar to those encoun-

tered in other forms of dense connective tissue. Since the lacunæ are compressed oval cavities lying between the lamellæ of the osseous matrix, when viewed in sections which pass through the layers at right angles (Fig. 117), the lacunæ present their narrower dimensions, appearing thus in profile as small lentiform spaces ; seen in sections, on the contrary, which pass parallel to the lamellæ (Fig. 118), the lacunæ are broader and more circular, the spaces with the canaliculi forming the spider-like figures so conspicuous in longitudinal sections of dried bone.

The characteristic arrangement of the lamellæ of the Haversian systems is due to the secondary formation of the osseous tissue during the conversion of the older spongy bone into compact tissue, the circumference of the system corresponding to the *Haversian space* in which the subsequent development of the concentric lamellæ

FIG. 115.



Longitudinal section of compact bone, ground and dried. × 85.

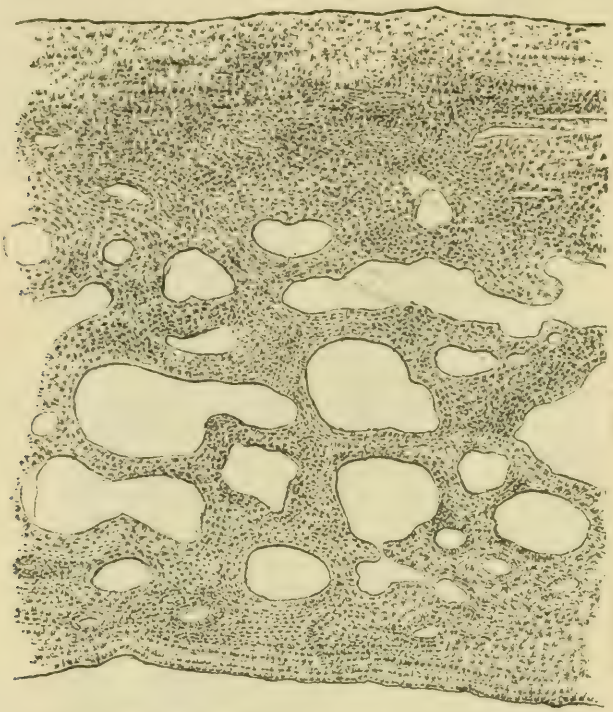
took place. It follows, from this relation, that Haversian systems exist only in compact bone, since the necessary secondary deposit does not occur during the growth of the spongy or cancellous tissue.

The lamellæ of osseous tissue, when deprived of the mineral matters and examined in thin fragments, often display the ultimate fibrous structure which they possess, since they consist of delicate fibrils of *fibrous tissue* embedded within a ground-substance and associated into bundles which are arranged as crossing and interwoven layers. Within the Haversian lamellæ the fibrous bundles cross generally at right angles, but in other locations they are less regularly and more acutely disposed.

The **perforating fibres** of Sharpey (Fig. 119) consist of bundles of fibrous tissue which penetrate the lamellæ in a direction perpendicular or oblique to their

surface, and thus pin or bolt the layers together. These fibres are especially numerous in the superficial lamellæ beneath the periosteum, to which membrane they owe their formation, and with which many seem to be directly continuous. They are

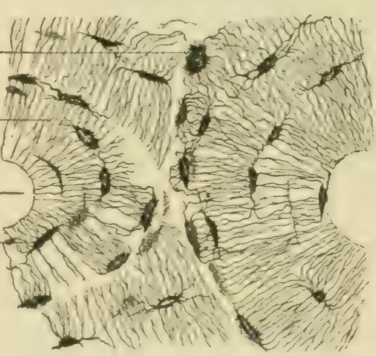
Fig. 116.



Section of frontal bone, showing the absence of Haversian systems. × 20.

readily found on the surfaces of the lamellæ of decalcified bone which have been forcibly separated. Although usually consisting of bundles of fibrous tissue, it is probable that in some cases the perforating fibres are elastic in nature. They are sometimes imperfectly calcified and leave, therefore, on drying, tubular canals, which pierce the lamella from the exterior of the bone. Since the perforating fibres are associated genetically with the periosteum, they are never found in the secondary lamellæ constituting the Haversian systems.

Fig. 117.



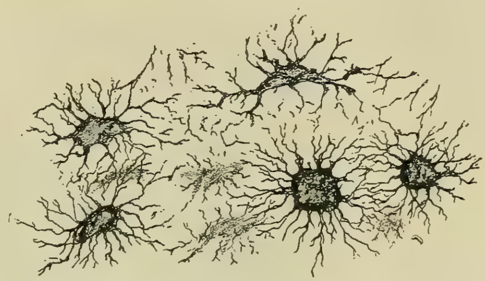
Portion of adjacent Haversian systems cut transversely. × 250.

The **Haversian canals** are continuations of the medullary cavity and serve the important purpose of conveying the blood-vessels within the compact substance ; from these vessels the nutritive fluids pass into the perivascular lymph-spaces between the walls of the canal and the blood-vessels and thence, by way of the canaliculi, which open into these lymph-spaces, into the adjacent lacunæ, and so on into the surrounding portions of the compact substance, the nutrition of which is thus maintained. Although the average size of the canals is about .05 millimetre, those next the medullary cavity are larger, some measuring .1 millimetre or more in diameter, and contain, in addi-

tion to the blood-vessels, an extension of the marrow-tissue. The individual channels are short, and communicate by oblique branches with adjacent canals (Fig. 115). The Haversian canals indirectly communicate with the external surface of the bone by means of the channels, or *Volkmann's canals*, within the circumferential lamellæ, which open by minute orifices and receive vascular twigs from the periosteal blood-vessels (Fig. 122); the latter are thus brought into free anastomosis with the branches derived from the medullary vessels, the two constituting a freely communicating vascular net-work throughout the compact substance.

The Bone-Cells.—The details of osseous tissue thus far considered pertain to the structure of the passive intercellular constituents of a dense connective tissue; in addition to these, as in other forms of connective substances, the more active elements are the connective-tissue cells, here known as the *bone-cells*. As already pointed out, the lacunæ and the canaliculi represent intercommunicating lymph-spaces, similar to those encountered in the cornea or other dense connective tissue; as in the latter so also in the osseous tissue, the cellular elements occupy the lymph-spaces, the bone-cells lying within the lacunæ. Since the classic pictures of bone are derived from ground sections of dried tissue, in such preparations the delicate bone-cells have shrunken and disappeared, and the lacunæ contain, at best, only the indistinguishable remains of the cells mingled with *débris* produced during the preparation of the section; the lacunæ and the canaliculi in dried sections are filled with air, by reason of which condition they appear as the familiar dark, sharply defined, conspicuous spider-like figures.

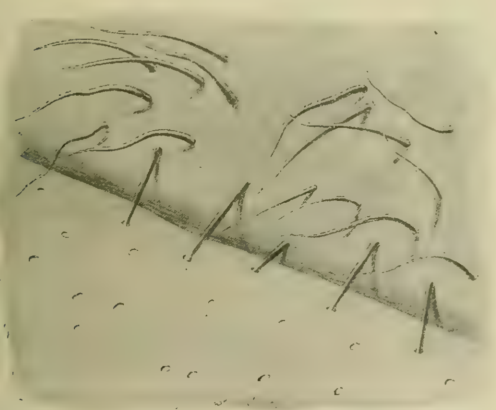
FIG. 118.



Lacunæ and canaliculi from dried bone cut parallel with the lamellæ. × 300.

In order to study the bone-cells, the tissue after fixation is decalcified and stained, and mounted in an approved preserving medium; in consequence of such treatment the air is displaced from the spaces within the bone, which now appear faintly outlined, the delicate ramifications of the canaliculi in places being almost invisible. The bone-cells, after being stained in such decalcified preparations, appear as small lenticular or stellate bodies within the lacunæ (Fig. 121), which they almost entirely fill. Each cell-body consists of granular cytoplasm from which delicate processes extend for a variable distance into the canaliculi, in favorable localities the protoplasmic processes sent out by adjacent bone-cells sometimes meeting. The deeply staining nucleus appears as a brilliant point within the stellate cell.

FIG. 119.



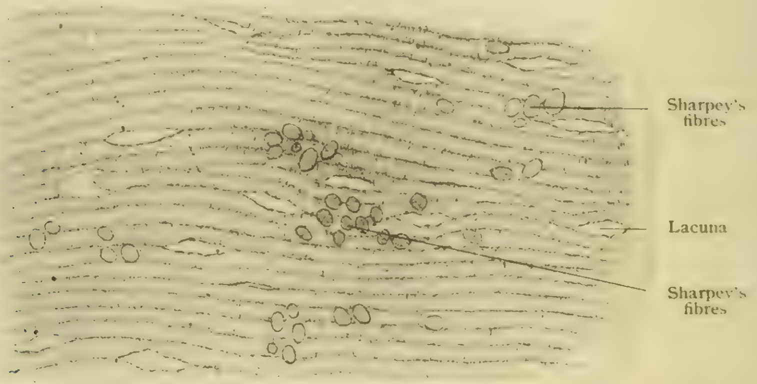
Semi-diagrammatic view of perforating fibres of Sharpey; the lamellæ of decalcified bone have been partially separated.

The Periosteum.—The external surface of bones is closely invested, except where covered with cartilage, with a fibrous membrane, the *periosteum*, a structure of great importance during development and growth, and later for the nutrition and protection of the osseous tissue. During childhood an end of the immature bone may be broken off and yet held in place by the periosteum. The adult periosteum consists of two layers, an outer *fibrous* and an inner *fibro-elastic;* when covering young bones, however, in which growth is actively progressing, the peri-

osteum contains an additional stratum, the *osteogenetic layer*, which lies closely associated with the exterior of the bone. After growth has ceased, the osteogenetic layer becomes reduced to an inconspicuous stratum included as part of the fibro-elastic constituent of the periosteum.

The *fibrous layer* is composed of closely placed bundles of fibrous connective tissue, and serves to support larger blood-vessels which break up within the deeper parts of the periosteum into the minute twigs entering the canals opening onto the surface of the bone.

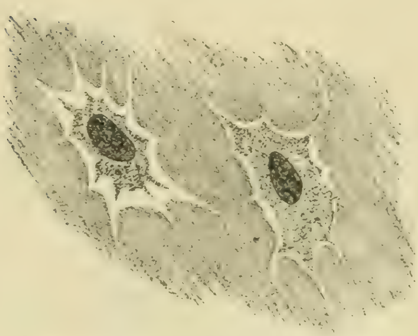
FIG. 120.



Oblique section of decalcified tibia, showing fibrous character of lamellæ and groups of Sharpey's fibres. × 420.

The *fibro-elastic* layer consists of a rich felt-work of elastic fibres, often arranged as several distinct strata ; the elastic tissue is separated from the surface of the bone by a layer of fibrous tissue comparatively rich in flat, plate-like connective-tissue cells, the remains of the elements of the osteogenetic layer. The inner surface of the periosteum is intimately attached to the osseous tissue by means of delicate processes of connective tissue which accompany the blood-vessels into the nutrient canals ; this relation persists from the continuity of the formative tissue of the young periosteum with the early marrow-tissue. Between the fibrous bundles next the bone numerous cleft-like lymph-spaces exist ; these are imperfectly lined by the endothelioid connective-tissue cells and communicate with the lymph-channels within the bone.

FIG. 121.



Bone-cells lying within the lacunæ. × 700.

The *osteogenetic layer*, conspicuous during the development and growth of the osseous tissue, consists of delicate bundles of fibrous tissue and large numbers of connective-tissue cells of an embryonal type. Those next the growing bone assume a low, irregular columnar form, and are disposed in rows upon the surface of the developing osseous tissue ; since these cells are concerned in the production of the latter, they are appropriately termed *osteoblasts*. Later some of them become surrounded by the bony matrix, and are thus transformed into bone-cells. The osteogenetic layer is rich in blood-vessels which, as the bone is formed, are continued into the primary marrow-cavities.

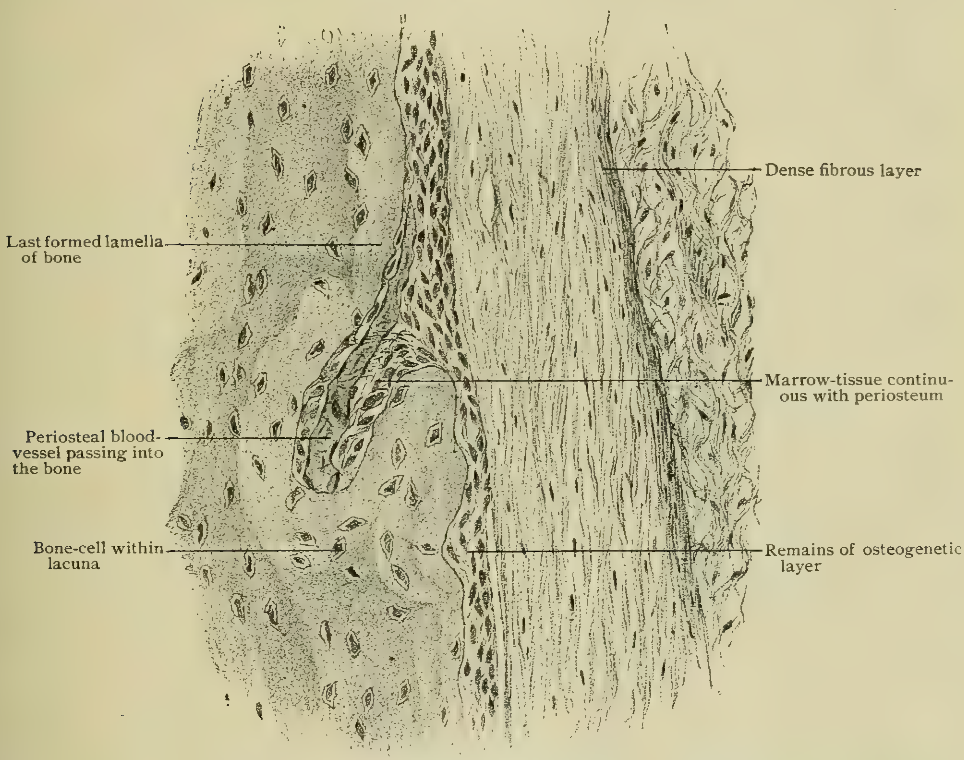
The Marrow. The spaces in the interior of bones, whether the large medullary cavities surrounded by the compact substance forming the shaft of the long bones or the irregular interstices between the trabeculæ composing the cancel-

lated tissue, are filled with bone-marrow. The latter also extends within the larger Haversian canals.

Although originally only of one variety within the bones of the early skeleton, the marrow in the adult consists of two kinds, the *yellow* and the *red*. Thus, within the shaft of the long bones it consists of a light yellowish tissue, presenting the characteristics of ordinary adipose tissue, while within the spaces of the cancellated tissue at the ends of the same bones the marrow appears of a dull red color. In addition to the ends of the long bones, the localities in which red marrow especially occurs are the bodies of the vertebræ, the ribs, the sternum, the diploë of the cranium, and the short bones.

Red Marrow.—The ingrowth of the periosteal tissue and blood-vessels constitutes the primary marrow within the embryonal skeleton ; from this tissue the red marrow filling the young bones is directly derived. The red marrow is, therefore,

FIG. 122.



Section of young periosteum and subjacent bone. × 275.

the typical and first formed variety within the fœtus and the young animal ; subsequently, that situated within the shaft of the long bones becomes converted into yellow marrow by the replacement of the majority of the marrow elements by fat-cells.

The red marrow (Fig. 123), when examined in section after fixation and staining, presents a delicate reticulum of connective tissue which supports the numerous medullary blood-vessels and the cellular elements. Next the bone the fibrous tissue forms a thin membrane, the *endosteum*, lining the medullary cavity and the larger Haversian canals into which the marrow extends. This membrane is highly vascular, its vessels joining those within the osseous canals on the one side and those of the marrow on the other.

The delicate fibrous reticulum, in addition to the thin-walled blood-channels which it supports, contains within its meshes the several varieties of elements char-

acteristic of the red marrow ; these are : (1) the *marrow-cells*, (2) the *eosinophile cells*, (3) the *giant cells*, and (4) the *nucleated red blood-cells*.

The **marrow-cells**, or *myelocytes*, resemble the large lymphocytes of the blood, but may differ from the latter in their slightly larger size and in the possession of a relatively large round or oval nucleus which contains comparatively little chromatin; the presence of neutrophile granules within the cytoplasm of the marrow-cells affords an additional differential characteristic when compared with the large lymphocytes in which these granules are absent.

The **eosinophile cells** occur in considerable numbers within the red marrow, and appear in varying stages of growth, as evidenced by their round *mononuclear*, the indented *transitional* and segmented *polymorphonuclear* condition ; the cells containing the latter form of nucleus are most abundant and represent, probably, the mature elements.

The **giant cells**, or *myeloplaxes*, are huge elements of irregular oval form, and contain simple or polymorphous nuclei. They represent specialized myelocytes,

FIG. 123.

Section of red marrow from epiphysis of young femur. × 300.

and during the processes resulting in the removal of osseous tissue they are the *osteoclasts* which are actively engaged in effecting the absorption of the bony matrix. Ordinarily the giant cells occupy the central portions of the marrow ; when, however, they enter upon the rôle of bone-destroyers, they lie on the surface of the osseous trabeculæ within the depressions known as *Howship's lacunæ* (Fig. 128).

The **nucleated red blood-cells** within the red marrow are concerned in the important function of renewing the colored cells of the blood, the red marrow being the chief seat in which this process takes place after birth ; hence the red marrow is classed as a *blood-forming organ*. The nucleated red blood-cells exist within the marrow in two forms, an older and a younger. The genetically older cells, the *normoblasts*, are the descendants of the embryonal nucleated blood-cells on the one hand and the indirect parents of the younger blood-elements on the other. The normoblasts possess relatively large nuclei, with chromatin reticulum and cytoplasm tinged with hæmoglobin ; they are frequently observed during mitosis, since they gave rise to the second generation of nucleated red blood-cells. The latter, the *erythro-*

blasts, are directly converted into the mature, non-nucleated red blood-disks on the disappearance of their nucleus. In addition to a larger amount of hæmoglobin in their cytoplasm, the erythroblasts differ from the normoblasts in the possession of a deeply staining nucleus, in which the chromatin no longer appears as a reticulum.

It is usual to find isolated groups of fat-cells distributed within the red marrow, although the amount of adipose tissue is very meagre in localities farthest removed from the medulla of the long bones. The varieties of leucocytes usually seen in the blood are also encountered within the red marrow in consequence of the intimate relations between the latter tissue and the blood-stream conveyed by the medullary capillaries.

Yellow Marrow.—Since the appearance of the yellow marrow is due to the preponderating accumulation of fat-cells which have replaced the typical elements of the marrow contained within the shaft of certain bones, the formation of this variety is secondary and must be regarded as a regression.

Examined in section, yellow marrow resembles ordinary adipose tissue, since it consists chiefly of the large oval fat-cells supported by a delicate reticulum of connective tissue. In localities in which the latter exists in considerable quantity, numerous lymphoid cells represent the remaining elements of the originally typical marrow-tissue. After prolonged fasting the yellow marrow loses much of its oily material and becomes converted into a gelatinous substance containing comparatively few fat-cells ; upon the re-establishment of normal nutrition this tissue may again assume the usual appearance of yellow marrow.

Blood-Vessels.—The generous blood-supply of bones is arranged as two sets of vessels, the *periosteal* and the *medullary*. The former constitutes an external net-work within the periosteum, from which, on the one hand, minute twigs enter the subjacent compact substance through channels (*Volkmann's canals*) communicating with the Haversian canals, within which they anastomose with the branches derived from the medullary system ; additional vessels, on the other hand, pass to the cancellated tissue occupying the ends of the long bones.

The *medullary artery* is often, as in the case of the long bones, a vessel of considerable size, which, accompanied by companion veins, traverses the compact substance through the obliquely directed *medullary canal* to gain the central part of the marrow. On reaching this position the medullary artery usually divides into ascending and descending branches, from which radiating twigs pass towards the periphery. The latter terminate in relatively narrow arterial capillaries, which, in turn, expand somewhat abruptly into the larger venous capillaries. Such arrangement results in diminished rapidity of the blood-stream, the blood slowly passing through the network formed by the venous capillaries. The latter vessels, within the red marrow, possess thin walls and an imperfect endothelial lining in consequence of which the blood comes into close relation with the elements of the medullary tissue. During its sluggish course within the blood-spaces of the red marrow, the blood takes up the newly formed red cells, which thus gain entrance into the circulation to replace the effete corpuscles which are continually undergoing destruction within the spleen. It is probable that leucocytes also originate in the bone-marrow.

After thus coming into intimate relations with the marrow-tissue, the blood is collected by capillaries which form small veins. In addition to the companion veins accompanying the nutrient artery along the medullary canal, in many instances the larger veins pursue a course independent of the arteries and emerge from the cancellous tissue by means of the canals piercing the compact substance at the ends of the bones. Although destitute of valves within the medulla, the veins possess an unusual number of such folds immediately after escaping from the bone.

Lymphatics.—The definite lymphatic channels of the bones are principally associated with the blood-vessels of the periosteum and the marrow as *perivascular channels*, although it is probable that lymphatic spaces exist within the deeper layers of the periosteum, in close relation to the osseous tissue. The perivascular lymphatics follow the blood-vessels into the Haversian canals, where, as well as on other surfaces upon which the canaliculi open, the system of intercommunicating juice-channels represented by the lacunæ and the canaliculi is closely related with the lymphatic trunks.

Nerves.—The periosteum contains a considerable number of nerves, the majority of which, however, are destined for the supply of the underlying osseous tissue, since those distributed to the fibrous envelope of the bone are few. The periosteal nerves follow the larger blood-vessels, in the walls of which they chiefly terminate. *Medullary* nerves accompany the corresponding blood-vessels through the medullary canal, and within the marrow break up into fibrillæ to be, probably, distributed to the walls of the vascular branches along which they lie. Regarding the ultimate endings and arrangement of the sensory fibres little is known; in view of the low degree of sensibility possessed by healthy bones and their periosteum, the number of such nerves present in osseous structures must be very small.

DEVELOPMENT OF BONE.

The bones composing the human skeleton, with few exceptions, are preceded by masses of embryonal cartilage, which indicate, in a general way, the forms and relations of the subsequent osseous segments, although many details of the modelling seen in the mature bones appear only after completed development and the prolonged exercise of the powerful modifying influences exerted by the action of the attached muscles. Since the primary formation of such bones takes place within the cartilage, the process is appropriately termed *endochondral development.*

Certain other bones, notably those forming the vault of the skull and almost all those of the face, are not preceded by cartilage, but, on the contrary, are produced within sheets of connective tissue; such bones are said, therefore, to arise by *intramembranous development.* It will be seen, however, that the greater part of the bone formed by endochondral development undergoes absorption, the spongy substance within the ends of the long and the bodies of the irregular bones representing the persistent contribution of this process of bone-production. Even in those cases in which the intracartilaginous mode is conspicuous, as in the development of the humerus, femur, and other long bones, the important parts consisting of compact substance are the product of the periosteal connective tissue, and hence genetically resemble the intramembranous group. Although both methods of bone-formation in many instances proceed coincidently and are closely related, as a matter of convenience they may be described as independent processes.

FIG. 124.

Clarified human fœtus of about three and one-half months, showing the partially ossified skeleton. Two-thirds natural size.

Endochondral Bone Development.—The primary cartilage, formed by the proliferation and condensation of the elements of the young mesoblastic tissue, gradually assumes the characteristics of embryonal cartilage, which by the end of the second month of intra-uterine life maps out the principal segments of the fœtal cartilaginous skeleton. These segments are invested by an immature form of perichondrium, or *primary periosteum*, from which proceed the elements actively engaged in the production of the osseous tissue. The primary periosteum consists of a compact outer *fibrous* and a looser inner *osteogenetic layer;* the latter is rich in cells and delicate intercellular fibres.

The initial changes appear within the cartilage at points known as *centres of ossification*, which in the long bones are situated about the middle of the future shaft. These early changes (Fig. 125) involve both cells and matrix, which exhibit conspicuous increase in size and amount respectively. As a further consequence of this activity, the cartilage-cells become larger and more vesicular, and encroach upon the intervening matrix, in which deposition of lime salts now takes place, as evidenced by the gritty resistance offered to the knife when carried through such ossific centres. On acquiring their maximum growth the cartilage-cells soon exhibit indications of impaired vitality, as suggested by their shrinking protoplasm and degenerating

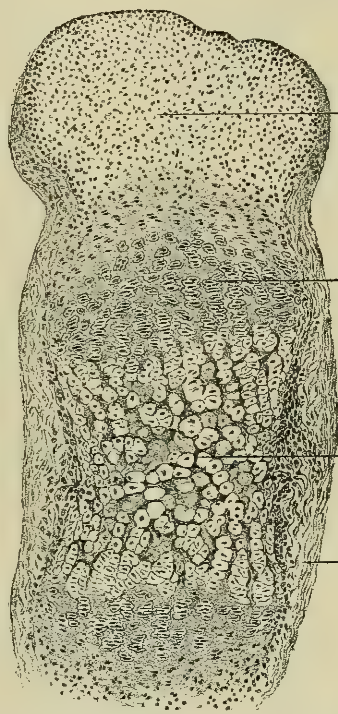
nuclei. The enlarged spaces enclosing these cells are sometimes designated as the *primary areolæ.*

Coincidently with these intracartilaginous changes, a thin peripheral layer of bone has been formed beneath the young periosteum ; from the latter bud-like processes of the osteogenetic layer grow inward from the periphery and invade the embryonal cartilage, by absorption of the cartilage-matrix gaining the centre of ossification and there effecting a destruction of the less resistant cells and intervening matrix. In consequence of the penetration of the periosteal processes and the accompanying absorption of the cartilage, a space, the *primary marrow-cavity*, now occupies the centre of ossification and contains the direct continuation of the osteogenetic layer. This tissue, the *primary marrow*, which has thus gained access to the interior of the cartilage, contributes the cellular elements upon which a double rôle devolves,—to produce osseous tissue and to remove the embryonal cartilage.

The cartilage-matrix closing the enlarged cell-spaces next the primary marrow-cavity suffers absorption, whereby the cartilage-cells are liberated and the opened spaces are converted into the *secondary areolæ*, and directly communicate with the growing medullary cavity. After the establishment of this communication, the cartilage-cells escape from their former homes and undergo disintegration, *taking no part in the direct production of the osseous tissue.*

Beyond the immediate limits of the primary marrow-cavity the cartilage-cells, in turn, repeat the preparatory stages of increased size and impaired vitality already described, but in addition they often exhibit a conspicuous rearrangement, whereby they form columnar groups separated by intervening tracts of calcified matrix (Figs. 126, 129). This characteristic belt, or *zone of calcification*, surrounds the medullary cavity and marks the area in which the destruction of the cartilage elements is progressing with greatest energy. In consequence of the columnar grouping of the enlarged cartilage-cells and the intervening septa of calcified matrix, an arrangement particularly well marked in the ends of the diaphysis of the long bones, a less and a more resistant portion of the cartilage are offered to the attacks of the marrow-tissue by the cell- and matrix-columns respectively ; as a result of this difference, the cells and the immediately surrounding partitions are first absorbed, while the intervening trabeculæ of calcified cartilage-matrix remain for a time as irregular and indented processes, often deeply tinted in sections stained with hæmatoxylin, which extend beyond the last cartilage-cells into the medullary cavity. These trabeculæ of calcified cartilage-matrix serve as supports for the marrow-cells assigned to produce the true bone, since these elements, the *osteoblasts*, become arranged along these trabeculæ, upon which, through the influence of the cells, the osseous tissue is formed.

FIG. 125.

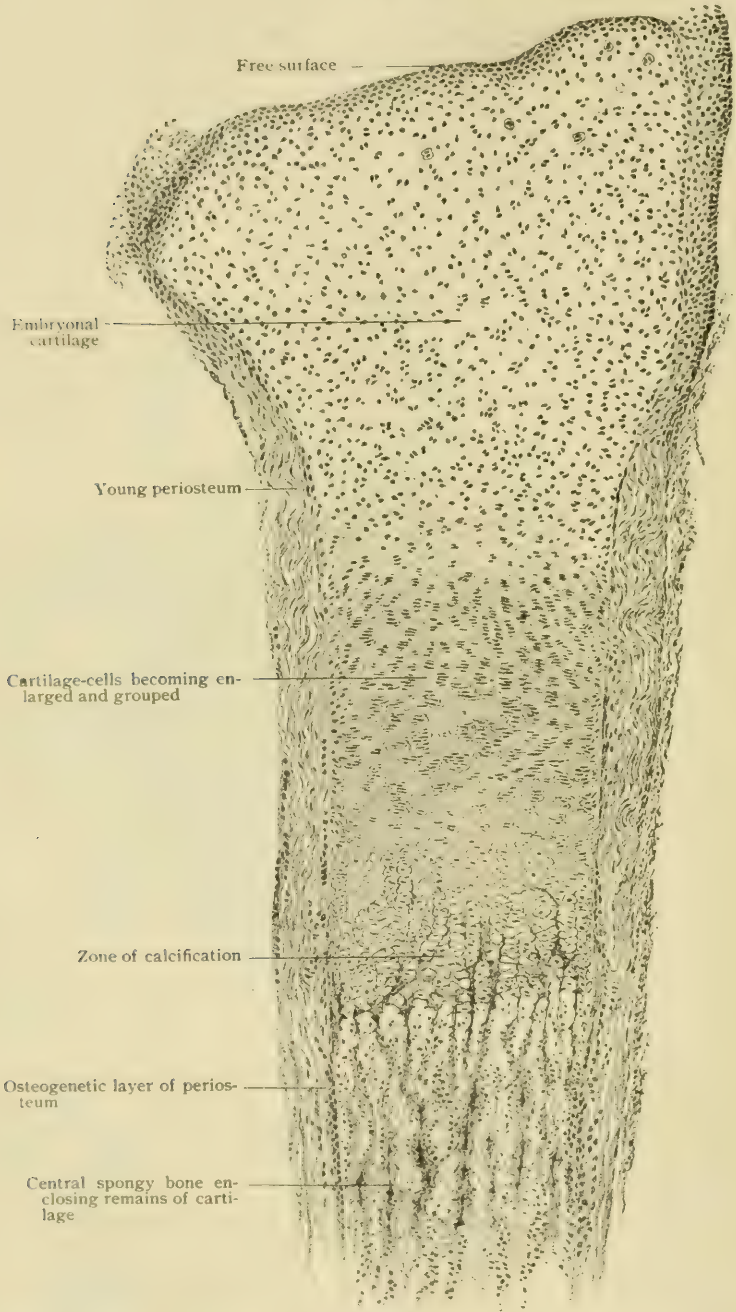


Section of tarsal bone of fœtal sheep, showing centre of ossification. × 50.

Simultaneously with the *destructive* phase attending the absorption of the cartilage, the *constructive* process is instituted by the osteoblasts by which the bone-tissue is formed. These specialized connective tissue elements, resting upon the

irregular trabeculæ of the calcified cartilage, bring about, through the influence of their protoplasm, the deposition of a layer of bone-matrix upon the surface of the

FIG. 126.



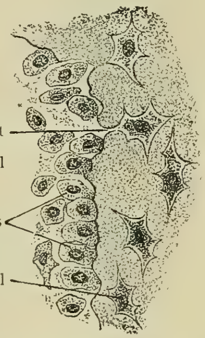
Longitudinal section of metatarsal bone of fœtal sheep, showing stages of endochondral bone-development. × 40.

trabeculæ, which thus becomes enclosed within the new bone. After the latter has attained a thickness of at least the diameter of the osteoblasts, some of the cells in closest apposition are gradually surrounded by the osseous matrix (Fig. 127), until,

finally, they lie isolated within the newly formed bone as its cells; the *bone-cells* are therefore imprisoned osteoblasts, which, in turn, are specialized connective-tissue elements. The bone-cells occupy minute lenticular spaces, the *primary lacunæ*, at this immature stage the canaliculi being still unformed. The early bone-matrix is at first soft, since the deposition of the calcareous materials takes place subsequently.

The increase in the thickness of the new bone is attended by the gradual disappearance of the enclosed remains of the calcified cartilage, the last traces of which, however, can be seen for some considerable time as irregular patches within the osseous trabeculæ (Fig. 131), somewhat removed from the zone of calcification. The cartilage and the bone of the trabeculæ stand, therefore, in inverse relations, since the stratum of bone is thinnest where the cartilage is thickest, and, conversely, the calcified matrix disappears within the robust bony trabeculæ. A number of the latter, together with the enclosed remains of the calcified cartilage, soon undergo absorption, with a corresponding enlargement of the intervening marrow-spaces. The remaining trabeculæ increase by the addition of new lamellæ on the surface covered by the osteoblasts, and at some distance from the zone of calcification form a trabecular reticulum, the primary *central spongy bone*. In the case of the irregular bones, the central spongy bone is represented by the cancellated substance forming the internal framework; in the long bones, on the contrary, the primary cancellated tissue undergoes further absorption within the middle of the shaft simultaneously with its continued development at the ends of the diaphysis from the cartilage. As the result of this absorption, a large space—the *central marrow-cavity*—is formed (Fig. 129), the growth of which keeps pace with the general expansion of the bone.

FIG. 127.



Section of a portion of osseous trabecula and fœtal marrow. × 375.

The absorption of the young osseous tissue to which reference has been made is effected through the agency of large polymorphonucleated elements, the *osteoclasts*. These are specialized marrow-cells whose particular rôle is the breaking up and absorption of bone-matrix. They are relatively very large, their irregularly oval bodies measuring from .050 to .100 millimetre in length and from .030 to .040 millimetre in breadth. The osteoclasts (Fig. 128), singly or in groups, lie in close relation to the surface of the bone which they are attacking within depressions, or *Howship's lacunæ*, produced in consequence of the erosion and absorption of the osseous matrix which they effect. When not engaged in the destruction of bone, these cells occupy the more central portions of the marrow-tissue, where, in the later stages, they are probably identical with the myeloplaxes or giant cells encountered in the red marrow.

FIG. 128.

Portion of trabecula of spongy bone undergoing absorption by osteoclast. × 500.

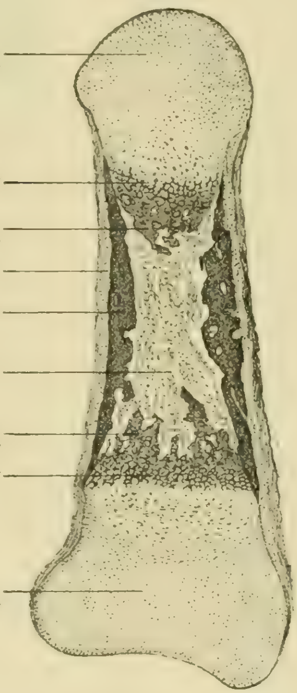
The only part of the central spongy bone which persists after the completed development and growth of the long bones is that constituting the cancellated tissue occupying their ends. It will be seen, therefore, in many cases, that the product of the endochondral bone-formation, the primary central osseous tissue, is to a large extent absorbed, and constitutes only a small part of the mature skeleton. The early marrow-cavity, as well as all its ramifications between the trabeculæ, is filled with the young marrow-tissue; the latter gives rise to the permanent red marrow

in the limited situations where the central spongy bone persists, as in the vertebræ, the ribs, the sternum, and the ends of the long bones.

The important fact may be here emphasized that the process sometimes spoken of as the "ossification of cartilage" is really a substitution of osseous tissue for cartilage, and that even in the endochondral mode of formation *cartilage is never directly converted into bone.*

The *ossification of the epiphyses* (Fig. 130), which in the majority of cases does not begin until some time after birth, the cartilage capping the diaphysis meanwhile retaining its embryonal character, repeats in the essential features the details already described in connection with endochondral bone-formation of the shaft. After the establishment of the primary marrow-cavity and the surrounding spongy bone, ossification extends in two directions,—towards the periphery and towards the adjacent end of the diaphysis. As this process continues, the layer of cartilage interposed between the central spongy bone and the free surface on the one hand, and between the central bone of the epiphysis and the diaphysis on the other, is gradually reduced until in places it entirely disappears. Over the areas which correspond to the later joint-surfaces the cartilage persists and becomes the articular cartilage covering the free ends of the bone. With the final absorption of the plates separating the epiphyses from the shaft the osseous tissue of the segments becomes continuous, "bony union" being thus accomplished.

Fig. 129.



Longitudinal section of phalanx of fœtus of five months. × 23.

Intramembranous Bone-Development.—The foregoing consideration of the formation of bone within cartilage renders it evident that the true osteogenetic elements are contributed by the periosteum when the latter membrane sends its processes into the ossific centre; the distinction, therefore, between endochondral and membranous bone is one of situation rather than of inherent difference, since in both the active agents in the production of the osseous tissue are the osteoblasts, and in essential features the processes are identical. Since in the production of membrane-bone the changes within pre-existing cartilage do not come into account, the development is less complicated and concerns primarily only a formative process.

Although the development of all osseous tissue outside of cartilage may be grouped under the general heading of intramembranous, two phases of this mode of bone-formation must be recognized; the one, the *intramembranous*, in the more literal sense, applying to the development of such bones as those of the vault of the skull and of the face, in which the osseous tissue is formed within the mesoblastic sheets, and the other, the *subperiosteal*, contributing with few exceptions to the production of every skeletal segment, in which the bone is deposited beneath rather than within the connective-tissue matrix. In consideration of its almost universal participation, the periosteal mode of development will be regarded as the representative of the intramembranous formation.

Subperiosteal Bone.—The young periosteum, it will be recalled, consists of an outer and more compact *fibrous* and an inner looser *osteogenetic* layer. The latter, in addition to numerous blood-vessels, contains young connective-tissue elements and delicate bundles of fibrous tissue. These cells, or *osteoblasts*, become more regularly and closely arranged along the fibrillæ, about which is deposited the

new bone-tissue, the osteoblasts becoming enclosed within the homogeneous matrix to constitute the bone-cells. The osseous trabecula thus begins to increase not only

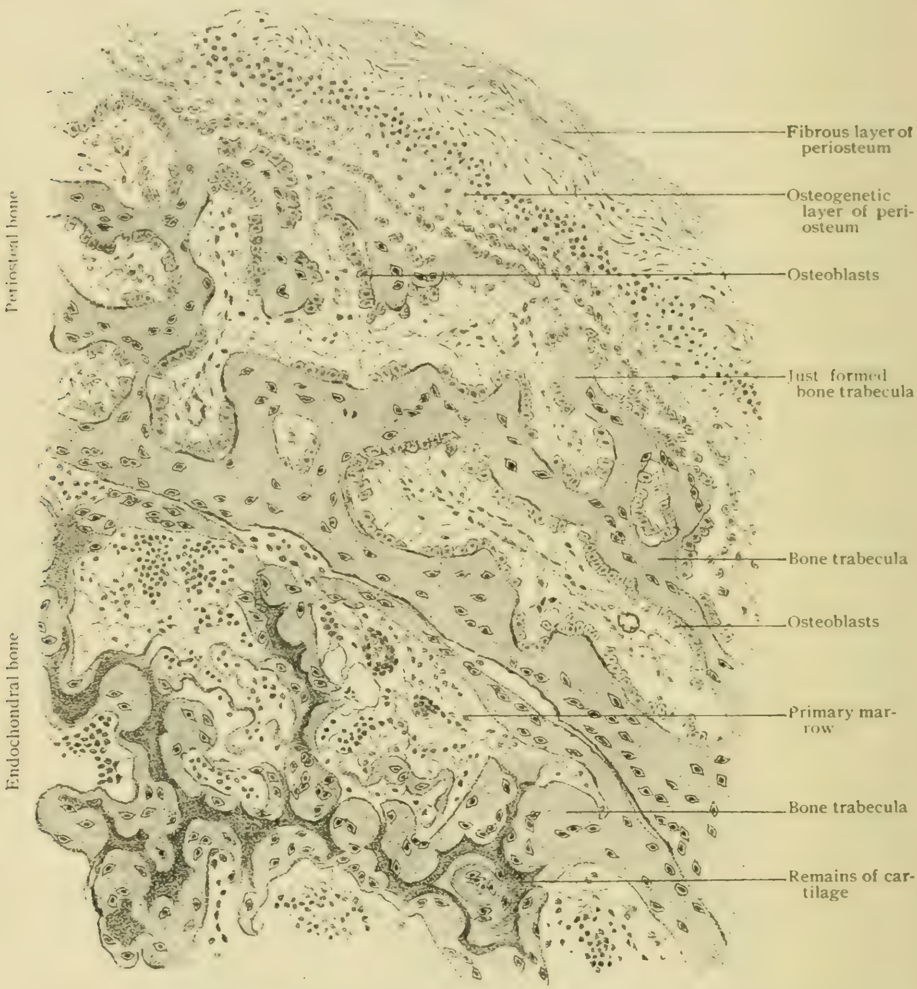
FIG. 130.

Longitudinal section including epiphysis and upper end of diaphysis of long bone of cat, just before osseous union of the head and shaft takes place. $\times$ 50.

in length, by the addition of the last-formed matrix upon the supporting fibres, but also in width, by the deposition of new layers of osseous material by the osteoblasts.

These cells cover the exterior of the trabeculæ as they lie surrounded by the young marrow-tissue which extends from the osteogenetic layer of the periosteum into the intertrabecular spaces. The union of the young trabeculæ results in the production of a subperiosteal net-work of osseous tissue, the *peripheral spongy bone*. The latter forms a shell surrounding the central endochondral bone, or, where the latter has already disappeared, the central marrow-cavity of the shaft. The two processes, central and peripheral bone-formation, progress simultaneously, so that the productions of both lie side by side, often in the same microscopical field (Fig. 131).

FIG. 131.



Portion of developing humerus of fœtal sheep, showing periosteal and central spongy bone. × 160.

The **development of compact bone** involves the partial absorption of the subperiosteal net-work of osseous trabeculæ and the secondary deposition of new bone-tissue. The initial phase in the conversion of the peripheral spongy bone into compact substance is the partial absorption of the trabeculæ by the osteoclasts of the primary marrow-tissue; in consequence of this process the close reticulum of periosteal bone is reduced to a delicate framework, in which the comparatively thin remains of the trabeculæ separate the greatly enlarged primary marrow-cavities, which, now known as the *Haversian spaces*, are of round or oval form.

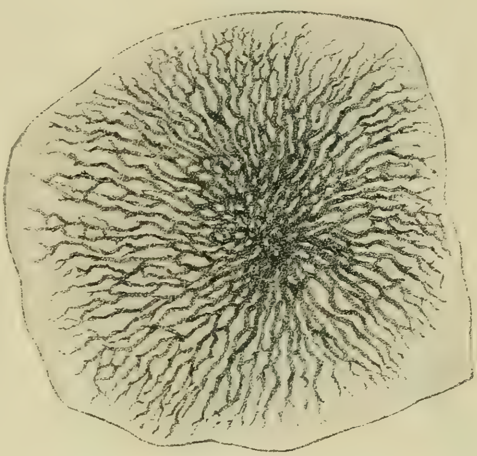
After the destructive work of the osteoclasts has progressed to the required extent, the osteoblastic elements of the young marrow contained within the Haver-

sian spaces institute a secondary formative process, by which new bone is deposited on the walls of the Haversian spaces. This process is continued until, layer after layer, almost the entire Haversian space is filled with the resulting concentrically disposed osseous lamellæ ; the cavity remaining at the centre of the new bone persists as the Haversian canal, while the concentrically arranged layers are the lamellæ of the Haversian system, the extent of the latter corresponding to the form and size of the Haversian space in which the secondary deposit of bone occurs. It is evident from the development of the compact substance that the interstitial or ground-lamellæ of the adult tissue correspond to the remains of the trabeculæ of the primary spongy bone ; these lamellæ are, therefore, genetically older than those constituting the Haversian systems. The details of the formation of the Haversian lamellæ, including the deposition of the matrix and the inclusion of the osteoblasts to form the bone-cells, are identical with those of the production of the trabeculæ of the earlier bone.

Intramembranous Bone.—The development of certain bones, as those constituting the vault of the skull and the greater part of the skeleton of the face, differs in its earliest details from that of the subperiosteal bone, although the essential features of the processes are identical. The mode by which these membrane-bones are formed may claim, therefore, a brief consideration.

The early roof of the skull consists, except where developing muscle occurs, only of the integument, the dura mater, and an intervening connective-tissue layer in which the membranous bones are formed. The earliest evidences of ossification usually appear about the middle of the area corresponding to the later bone, delicate spicules of the new bone radiating from the ossific centre towards the periphery. As the trabeculæ increase in size and number they join to form a bony net-work (Fig. 132), close and robust at the centre and wide-meshed and delicate towards the margin where the reticulum fades into the connective tissue. With the continued growth of the bony tissue the net-work becomes more and more compact until it forms an osseous plate, which gradually expands towards the limits of the area devoted to the future bone. For a time, however, until the completion of the earliest growth, the young bones are separated from their neighbors by an intervening tract of unossified connective tissue. Subsequent to the earlier stages of the formation of the tabular bones, the continued growth takes place beneath the periosteum in the manner already described for other bones.

FIG. 132.



Parietal bone of human fœtus of three months, showing trabecular net-work of intramembranous bone. × 5.

On examining microscopically the connective tissue in which the formation of membrane-bone has begun, this layer is seen to contain numerous *osteogenetic fibres* around and upon which are grouped many irregularly oval or stellate cells ; the latter correspond to the *osteoblasts* in other locations, since through the agency of these elements the osseous matrix is deposited upon the fibres. As the stratum of bony material increases some of the cells are enclosed to form the future bone-corpuscles. Although the osteogenetic fibres correspond to delicate bundles of fibrous tissue, they are stiffer, straighter, and present less indication of fibrillar structure. Since the fibres forming the ends of the bony spicules generally spread out, they frequently unite and interlace with the fibres of adjacent spicules, thus early suggesting the production of the bony net-work which later appears.

Growth of Bone.—It is evident, since the new bone is deposited beneath the periosteum, that the growth of the subperiosteal bone results in an increased diame-

ter of the shaft as well as in thickening of the osseous wall separating the medullary cavity from the surface. In order, therefore, to maintain the balance between the longitudinal growth of the medullary cavity, effected by the absorption of the endochondral bone, and its lateral expansion, the removal of the innermost portions of the subperiosteal bone soon becomes necessary. Absorption of the older internal trabeculæ thus accompanies the deposition of new osseous tissue at the periphery ; by this combination of destructive and formative processes the thickness of the cylindrical wall of the compact substance of the diaphysis is kept within the proper limits and the increased diameter of the medullary cavity insured.

Throughout the period of early growth the increase in length of the bone is due to the addition of new cartilage at the ends ; later, the cartilaginous increments, contributed by the chondrogenetic layer of the perichondrium, are supplemented by interstitial expansion following the multiplication of the existing cartilage-cells. On attaining the maximum growth and the completion of epiphyseal ossification, a portion of the cartilage may persist to form the articular surfaces. After the cessation of peripheral growth and the completion of the investing layer of compact substance, the osteogenetic layer of the periosteum becomes more condensed and less rich in cellular elements, retaining, however, an intimate connection with the last-formed subjacent bone by means of the vascular processes of its tissue, which are in continuity with the marrow-tissue within the intraosseous canals. In addition to being the most important structure for the nutrition of the bone, on account of the blood-vessels which it supports, the periosteum responds to demands for the production of new osseous tissue, whether for renewed growth or repair, and again becomes active as a bone-forming tissue, its elements assuming the rôle of osteoblasts in imitation of their predecessors.

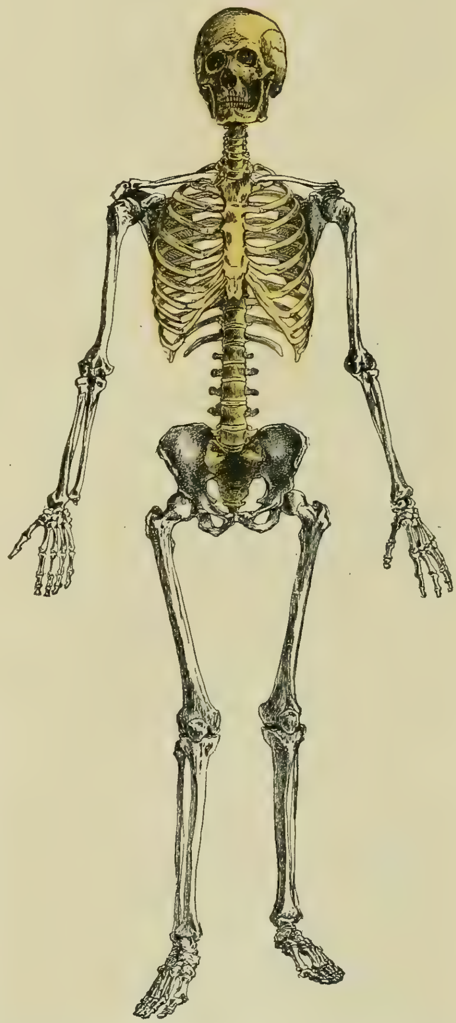
THE SKELETON:

INCLUDING

THE BONES AND THE JOINTS.

THE skeleton forms the framework of the body. In the widest sense it includes, besides the bones, certain cartilages and the joints by which the different parts are held together. The skeleton of vertebrates is divided into the *axial* and the *appendicular;* the former constitutes the supporting framework of the trunk and head ; the latter, that of the extremities.

FIG. 133.



The tinted portions constitute the axial skeleton; the untinted, the appendicular skeleton.

The Axial Skeleton.—The general plan of the axial skeleton of the trunk is as follows : a rod composed of many bony disks (the vertebral bodies) connected by fibro-cartilage separates two canals, a dorsal and a ventral. In most vertebrates the rod is in the main horizontal, with the dorsal canal above and the ventral below ; but in man the rod is practically vertical, with the dorsal canal behind and the ventral in front. The former is called the *neural*, because it encloses the central nervous system ; the latter, the *visceral*. The *vertebral column* has developed about the primary axis, the *notochord*. The neural canal is enclosed by a series of separate arches springing one from each vertebra. The skeletal parts of the anterior, or ventral, canal are less numerous ; they are the *ribs*, the *costal cartilages*, and the *breast bone*. Above is the bony framework of the head, or the *skull*. This also is divided into a dorsal and a ventral portion by a bony element which is apparently a continuation of the bodies of the vertebræ, and, indeed, is actually developed, in part, around the front of the notochord. The cephalic axis, however, is bent at an angle with the vertebral bodies, so that the neural arches, which here enclose the brain, are chiefly no longer behind but above. Below and in front of the brain-case is the *face*, which contains the beginning of the *digestive tube*, of which the jaws and teeth are special organs. In the head we do not find the separation of the parts enclosing the brain into a series of vertebræ, but they are clearly a continuation of the vertebral arches, the posterior, or occipital, division strongly suggesting a vertebra. The face is far more complicated, the vertebral plan being lost. In short, the axial skeleton consists of a

central, many-jointed rod bent forward near the top, with very perfect bony walls behind and above it, enclosing the central nervous system, and very imperfect bony and cartilaginous walls before and below it, enclosing the digestive apparatus and its associates, the circulatory, respiratory, urinary, and reproductive organs.

The **Appendicular Skeleton** has an entirely distinct origin; it is the framework of the limbs. It consists of two *girdles*, a *thoracic* and a *pelvic*, to each of which is attached a series of segments, the terminal one of which expands into five rays,—*fingers* and *toes*. According to some anatomists, the true vertebrate plan is of seven terminal rays, but, the question being still undecided, the more usual system is followed. Each of these rays consists of three or four bones. Proximal to this comes a series of short bones,—*wrist* and *ankle*; still nearer, a pair of bones,—*forearm* and *leg*; then a single bone, *arm* and *thigh*; and lastly a bony arch,—the *girdle*.

In man, the thoracic girdle, made up of collar-bone and shoulder-blade, lies external to the chest, while the pelvic girdle fuses on each side into one bone, meets its fellow in front, and unites with the bodies of certain vertebræ. Thus, besides bearing a limb, the pelvic girdle forms a part of the wall of the abdominal and the pelvic cavities and would seem to belong to the axial skeleton, but embryology and comparative anatomy show that it does not.

GENERAL CONSIDERATION OF THE BONES.

The bones have the physiological function of bearing weight, of affording protection, and especially, by the systems of levers composing the limbs, of effecting movements through the action of the muscles. They must, therefore, be capable of resisting pressure, accidental violence, and the strain caused by the pull of the muscles. The size of the bones must be such that besides serving the obvious needs of support and protection they may be sufficiently large to offer adequate surface for the origin and insertion of muscles, and the shape must be such as to allow this without undue weight.

Shapes of Bones. Bones are divided, according to their form, into *long*, *flat*, and *irregular*; such classification, however, is of little value, since many bones might be variously placed.

Long bones form the best-defined group. They consist of a shaft and two extremities, each of which takes part in the formation of a joint, or, as in the case of the last phalanges, is terminal.

Flat bones, where very thin, consist of a single plate; where thicker, they consist of two plates separated by spongy substance called diploë.

Irregular bones may be regarded as embracing all others. The group of the so-called *short bones* has no significance.

Sesamoid Bones, with the exception of the patella, are not usually included in the description of the skeleton. With the above exception, they are small rounded bones developed, for the most part, in the capsules of joints, but sometimes in tendons. Usually one surface is cartilage-covered, and either enters into the formation of a joint or, separated by a bursa, plays on another bone, or on cartilage or ligament. Their function is to obviate friction, and, in some cases, to change the direction of the pull of a muscle. The number of sesamoid bones is very variable; but the usual idea that they are, so to speak, accidental, depending on the mechanics of a certain joint or tendon, must probably be abandoned. They are rather to be considered as real parts of the skeleton,[1] all of which have their places in certain animals, but all of which either are not developed, or, if they do appear, are again lost in others. Thus, certain sesamoid bones of the fingers are very frequent in the fœtus and very rare in the adult.

Growth of Bones.—The microscopical details of bone-growth are given elsewhere (page 94). Suffice it to say here that each bone has certain so-called *centres of ossification* from which the formation of the new bone spreads. In the long bones there is one main centre in the shaft, or *diaphysis*, which appears in the first half of fœtal life. Other centres appear, usually some time after birth, in the ends of the

[1] Thilenius: Morpholog. Arbeiten, Bd. vi., 1896.

bones. There may be one or several in each end. The part formed around each of these secondary centres is called an *epiphysis*. Growth takes place chiefly in the cartilage between the epiphyses and the shaft. When, therefore, a joint is resected in childhood the surgeon tries to leave a part of the epiphysis in place. A curious relation exists between the course of the chief medullary artery of the shaft of a long bone and the behavior of the epiphyses. The epiphysis towards which the vessel is directed is the last to appear and the first to unite. (The fibula furnishes an exception.) As a rule, also, the largest epiphyses appear first and unite last. In long bones with an epiphysis at one end only, the nutrient canal leads towards the opposite extremity.

Mechanics of Bone.—A long bone has a hollow shaft containing *marrow*, the wall being of compact bone. The hollowness of the shaft takes from the weight, and, moreover, conforms to the well-known law that a given quantity of matter is much stronger, both lengthwise and crosswise, when disposed as a hollow cylinder than as a solid one of equal length. The proportion of the central or medullary cavity is not the same in all bones. Perhaps, as an average, its diameter may be said to equal one-third of that of the bone. In the shaft this cavity is crossed by a few bony trabeculæ, almost all of which are destroyed in maceration. Towards the ends, as the outer wall becomes thinner, large numbers of thin plates spring from its inner surface and incline towards one another in graceful curves, until at last the expanded end of the bone consists of spongy or cancellated tissue enclosed within a delicate wall of compact substance. The arrangement of these plates is distinctly purposeful, since it has been shown that they are so disposed as to correspond with the stress-lines an engineer would construct for the special purpose served by the end of the bone. None the less, it would be unwarranted to maintain that mathematical correctness is always to be found, or that there are not other modifying influences. The internal structure of all bones, excepting, perhaps, those of the skull, is of this nature, so that the following remarks apply to spongy bone in general.

The delicate cancellated structure is for the most part in thin plates. The simplest arrangement occurs in a short bone exposed to pressure only at two opposite surfaces ; in such cases the plates run between these surfaces with few and insignificant cross-pieces. Where severe pressure may come in almost any direction, as in the case of the globular heads of the humerus and femur, the *round-meshed* pattern predominates, producing a very dense spongy structure which may be represented diagrammatically by drawing lines crossing at right angles and by enlarging every point of intersection. In the midst of this round-meshed type there is very frequently a central core with stronger plates and larger spaces. The *vaulted* system is found at the projecting ends of bones, and between the round-meshed cancellated substance and the shaft. Several special arrangements will be described in connection with the bones in which they occur. An *epiphysis*, until it has fused, shows the mechanical structure of a separate bone. A *process* for the attachment of muscles or ligaments generally contains a very light internal structure, the surface of the shaft of the bone being rarely continued under it. The continuation of the fibres of attached tendons is not represented by internal plates of bone, although the opposite opinion has supporters.

Certain of the bones of the cranium and the face are in parts hollowed out into mere shells bounding a cavity lined with mucous membrane continuous with that of the nose or the pharynx.

The **elasticity of bones** is enhanced by curves. The long bones very usually present a double curve. It has been maintained that these curves form a spiral structure. There are striking instances of it, but the universality of the law is not proved ; although shocks are thus lessened, the passage of one curve to another is a weak point in the bone.

The ends of the long bones are enlarged for articulation with their neighbors. The greater part of this enlargement forms the joint, the various shapes of which will be discussed later. Besides this, there are usually at the ends prominences for muscles. The shaft generally bears ridges, which in some cases are made of dense bone and materially add to the strength of the bone. A ridge or prominence usually implies the insertion of a fibrous aponeurosis or a tendon. Muscular fibres, however, may spring from the periosteum over a flat surface.

Parts of Bones.—The following are some of the names applied to features of bone:

A *process* is a general term for a projection.

A *spine* or *spinous process* is a sharp projection.

A *tuberosity* is a large rounded one, a *tubercle* is a small one, either rounded or pointed.

A *crest* is a prominent ridge.

A *head* is an enlargement at the end of a bone, in part articular.

A *neck* is a constriction below a head.

A *condyle* is a rounded articular eminence, generally a modification of a cylinder.

A *fossa* is a pit.

A *glenoid cavity* is a shallow articular depression.

A *cotyloid cavity* is a deep one.

A *sulcus* is a furrow.

A *foramen* is a hole, in the sense of a perforation.

A *sinus* is the cavity of a hollow bone, equivalent to *antrum*. It is used also to designate certain grooves for veins in the cavity of the cranium.

In addition to the cartilage-covered articular surfaces proper, the fresh bones show in some places a plate of cartilage quite like one for a joint; such plates serve to lessen the friction of a tendon playing over the bone. In other places a look of peculiar smoothness is conferred by the presence of a bursa, although cartilage is wanting.

Sex of Bones.—Female bones are characterized in general by: (*a*) a greater slenderness; (*b*) a smaller development of processes and ridges for muscular attachment[1]; (*c*) and, most important of all, the small size of the articular surfaces. These guides usually suffice to determine the sex of the chief bones; some, especially those of the pelvis, possess characteristic sexual differences of form.

Age of Bones.—*At birth* the long bones have cartilaginous ends in which, with one or two exceptions, the centres of ossification have not yet appeared. Many bones at this period still consist of several pieces which ultimately fuse. The shape and proportions are in some cases different from those of the adult. Sexual differences cannot in most cases be determined. During the *first years* new centres of ossification appear, distinct pieces unite, and the proportions change from the type of the infant to that of the child. Towards puberty important further changes in proportion occur, and sexual differences develop.

After puberty the bones present three stages,—*adolescence*, *maturity*, and *senility*. In the first the union of the epiphyses is going on; after this has taken place the line of separation is visible for a time, but gradually disappears. Our knowledge of the time at which these changes occur enables us to determine the age of the skeleton. The long period of maturity presents little that allows of a precise estimate of age. The separate bones of the vault of the cranium gradually fuse into one. The senile skeleton in its extreme stage is very striking. There is a general atrophy of the bones both within and without, those of the face becoming in parts of papery thinness; not only the cavities within the cranial bones become larger, but also the spaces within the cancellous tissue inside the bones, due to the partial absorption of the spongy substance. The only bones, however, which show a distinct change of form are the jaws, and this is a secondary result of the loss of the teeth. In many cases, however, senile absorption and atrophy do not occur, except, perhaps, in the head; it may be, therefore, absolutely impossible to distinguish a long bone of an old subject from one of an individual in early maturity. The periods at which the age of bones is most often a matter of medico-legal inquiry are at the time of birth and in childhood and youth. The dates of the first appearance of ossification in the various bones are the criteria for the first. These are to be used, however, with great caution, since variation is considerable. The information to be derived from consideration of the general development of the body is perhaps of equal value. The same holds good for childhood and adolescence. The particular point on which the writer holds strong views, based on his own observations, differing from those generally accepted, is as to the time of union of the epiphyses at the end of ado-

[1] Dwight: American Journal of Anatomy, Vol. iv., 1904.

lescence. He is convinced, as his statements will show, that this union occurs earlier than is generally taught.

Relation of the Bones to the Figure.—While it may be said that powerful muscles leave their imprint on the bones in strong, rough ridges, yet it is impossible to give a trustworthy description of the figure from the size and shape of the bones, since these are determined chiefly by prenatal influences. Very delicate, even puny, bodies may have large and strong bones, and great muscular development may coexist with a light framework.

Variations.—Besides the great range of individual variation, without departure from the usual type, bones occasionally show greater peculiarities. These may occur through either excess or defect of ossification. Structures which are normally cartilaginous or fibrous may become replaced by bone, and abnormal foramina may occur in consequence, or to accommodate the aberrant course of blood-vessels or nerves. The most interesting of these variations are such as present an arrangement which is normal in some of the lower animals. Many variations may be plausibly accounted for as reversions, but others cannot be explained in this way according to any conceivable scheme of descent. By speaking of these variations as animal analogies we avoid theories and keep to scientific truth.

Number of Bones.—The usual enumeration of the bones composing the human skeleton is misleading, for while it is customary in some parts, as the head, to count each bone, in others, like the sacrum and the hyoid, only the ultimate condition, after union of the component segments, is considered. In other cases, like the sternum, there may be grave doubt which course is the proper one to follow ; and finally, as in the coccyx, the number is variable. Bearing these important facts in mind, it may be stated that the human skeleton in middle life usually comprises, as conventionally reckoned, two hundred separate bones, excluding the sesamoids within the tendons of the short flexor of the thumb and of the great toe and the ear-ossicles, but including the patella and the hyoid bone. Of this number, seventy-four bones belong to the axial and one hundred and twenty-six to the appendicular skeleton.

The skeleton is advantageously described in the following order : the spine, the thorax, the head, the shoulder-girdle and the arm, the pelvic girdle and the leg. The account of the bones of each region is succeeded by that of the joints and the ligaments holding them together, followed by a consideration of the region as a whole and of its relation to the surface. The applications of anatomical details of the skeleton to the requirements of medicine and surgery are pointed out in appropriate places.

GENERAL CONSIDERATION OF THE JOINTS.

A JOINT or articulation implies the union of two or more bones. Joints may be divided, according to their mobility, into three great classes : the FIXED JOINT (*Synarthrosis*), the HALF-JOINT (*Amphiarthrosis*), and the TRUE JOINT (*Diarthrosis*).

Fixed Joints.—These allow no motion in the mature condition, and are represented by two subdivisions, the *Suture* and the *Synchondrosis.*

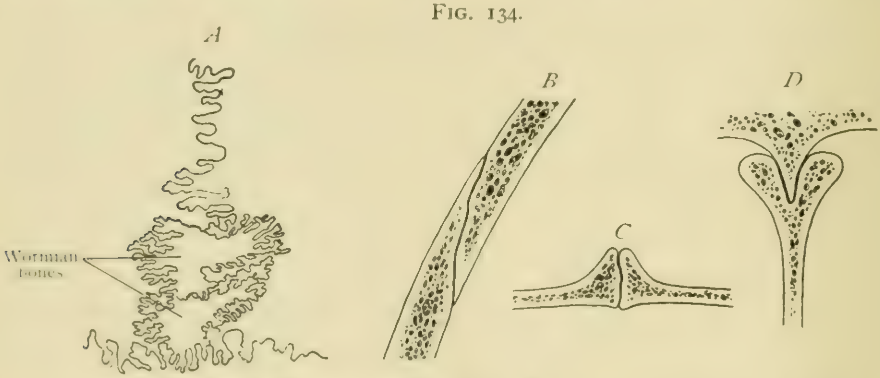
The **suture** is the direct union of two bones which at first may be separated by membrane or by fibrous tissue, but which eventually become firmly united. Several varieties of this form of union are recognized ; thus a *serrated suture* is one in which the edges are interlocked, as the teeth of two saws ; conspicuous examples are seen in the interparietal and the parieto-occipital junctures. Frequently one bone tends to overlap at one end of the suture and to be overlapped at the other. A *squamous suture* is one in which a scale-like bone very much overlaps another, as in the relation between the temporal and the parietal bone. An *harmonic suture* is one in which two approximately plane surfaces are apposed, as in the case of the vertical plate of the palate and the maxillary bone. The term *grooved suture* is sometimes employed to designate a form of union in which one bone is received within the grooved surface of another, as the rostrum of the sphenoid and the vomer. *Wormian bones* are small, irregular ossifications which appear as bony islands in the course of a suture. Familiar examples of these are seen in the line of the parieto-occipital suture.

Synchondrosis is the union of two bones by an intervening strip of cartilage, which usually ultimately becomes replaced by bone. Such is the union between the pieces of the body of the sternum and between certain bones of the base of the skull. The term is also applied to the union of the shaft and the epiphyses of long bones.

Half-Joints, including *Symphysis* and *Syndesmosis*. From the stand-point of development, there is no fundamental difference between symphyses and the true joints. In both cases a small cavity appears within the intervening mesoblastic tissue connecting the ends of the embryonal bones. This small cavity, in the case of the true joints, rapidly increases, and later is lined by the flattened mesoblastic cells investing the subsequently differentiated synovial membrane. When, on the contrary, the bones are to become united by dense fibrous and fibro-cartilaginous tissue, as in the case of a symphysis, the interarticular space is always a mere cleft surrounded by the interlacing and robust bundles of the dense tissue forming the union in the mature joint.

A symphysis implies great strength and very limited and indefinite motion, there being no arrangement of surfaces to determine its nature. The chief function of this form of union seems rather to be to break shocks. The central cavity is not always found. The symphysis pubis (Fig. 361) is a typical half-joint. Those connecting the bodies of the vertebræ are usually so classed, but it is not certain that they quite agree either in structure or development with the description. A transi-

FIG. 134.



Diagrams of various forms of suture. *A*, serrated; *B*, squamous; *C*, harmonic; *D*, grooved.

tional form leading from the symphysis to the true joint is one in which the limited synovial cavity, instead of being in the centre of a mass of fibro-cartilage, lies between two cartilaginous surfaces, somewhat like that of a true joint, but so interlocked and surrounded by short, tense fibres as to preclude more than very slight motion. This arrangement is often seen in the articulation between the sacrum and ilium, sometimes improperly called the sacro-iliac synchondrosis.

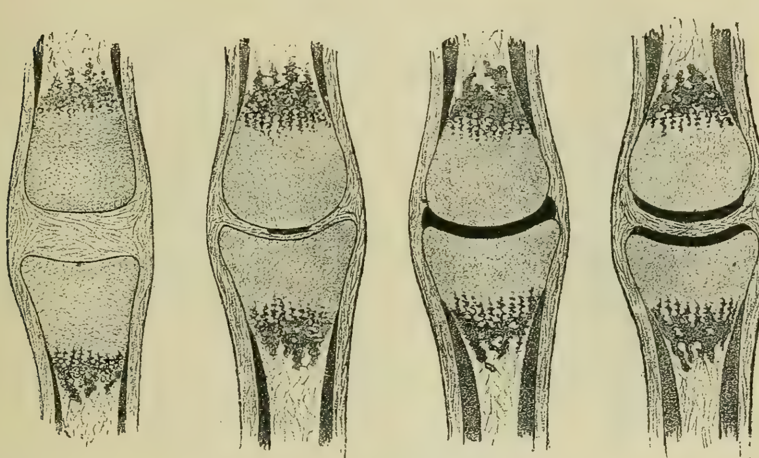
Syndesmosis is to be included among the half-joints. It is the binding together of bones by fibres, either in bundles or as a membrane, without any intervening cartilage; an example of this arrangement is seen in the union effected by the interosseous ligament in the lower tibio-fibular articulation.

True Joints.—These articulations develop in a similar manner to the half-joints, except that the opposed ends of the developing bones are of hyaline cartilage, fibro-cartilage being present only at the sides, except in the case of a compound joint, where it forms the intervening plate. The tissue at the sides of the articular cleft differentiates into two layers,—the inner, which is the *synovial membrane*, consisting of a layer of cells continuous with the superficial layer of the cartilage-cells and secreting a viscid fluid, the *synovia*, which lubricates the joint; and the outer part, which becomes a fibrous bag called the *capsular ligament*. The latter, in its simplest form, consists of only enough fibrous tissue to support the synovial membrane. The capsular ligament is strengthened by *accessory ligaments* developing in or around it, the arrangement of which depends on the needs of the joint. During development,

independent of the influence of motility or of muscular action, the articular ends of the bones assume definite shapes such as will allow the motion peculiar to that joint, and (barring the frequent want of perfect coaptation) no other. The common characteristics of true joints are *articular surfaces* covered by hyaline cartilage, so shaped as to determine the nature of the movement, enclosed by a *capsule* lined with a *synovial membrane*. The articular surfaces are not necessarily formed wholly of bone, since very often increased concavity is secured by the addition of a lip of fibro-cartilage to the margin of the bone ; in other cases ligaments coated with cartilage complete a socket ; or again, disks of fibro-cartilage loosely attached to the periphery may project into a joint and partially subdivide it, following one bone in certain movements and the other in others.

Compound joints result from the persistence and differentiation of a portion of the tissue uniting the ends of the embryonal bones into a partition which, in the complete compound joint, separates the two synovial cavities developed, one on either side of the septum. The tissue between the bones becomes a fibro-cartilaginous disk,[1] which partially or completely subdivides the cavity. In such a joint, when typical, there are two ends of bone covered with articular cartilage, separated

FIG. 135.



Diagrams illustrating formation of joints. *A*, bones are united by young connective tissue; *B*, appearance of joint-cavity; *C*, differentiation of joint-cavity and capsule; *D*, development of two joint-cavities separated by fibrous septum, resulting in a compound joint.

by a fibro-cartilaginous disk or *meniscus*, and two distinct synovial membranes. The movements are, however, still determined to a considerable extent by the shape of the bones, so that these articulations may be classed as true joints. The fibro-cartilaginous meniscus may be replaced by a row of bones as in the wrist.

Structure of True Joints.—The opposed ends of the bones, and sometimes other tissues, are coated with hyaline *articular cartilage*, which gives a greater smoothness to the articulating surfaces than is found on the macerated bones. Though following in the main the bony contours, the cartilage does not do so accurately ; details are found on the cartilage that are obscure on the bones. It diminishes the force of shocks. Although, as already stated, the shape of the articular ends determines the nature of the motion, it is important to recognize that, as in the case of saddle-joints, the opposed surfaces are not so accurately in apposition that irregular movements cannot and do not occur. Failure to appreciate this fact has given rise to much difficulty in accounting for motions that undoubtedly take place, but which, according to the mathematical conception of the joint, are impossible. Further, the range of individual variation is great ; just as a man may have a long or a short head, so any of the articular ends of his bones may depart considerably from the average proportions. It is even possible in some of the smaller joints that

[1] Discus articularis.

the articular surface of a certain bone may be plane, convex, or concave in different persons.

The capsule.—Every joint, with possibly some exceptions in the carpus and the tarsus, is enclosed by a *capsule*,[1] or *capsular ligament*, which arises from the periosteum near the borders of the articular cartilage and surrounds the joint. This envelope consists of a membrane, often containing fat within its meshes, composed of two layers, the inner delicate *synovial membrane* and the external *fibrous layer*. The latter, while in some places very thin, is usually strengthened by the incorporation of fibrous bands which, from their position, are known as *lateral*, *anterior*, or *posterior ligaments*. These bands are of strong, non-elastic fibrous tissue which under ordinary circumstances do not admit of stretching. The strength and security of the joint are often materially increased through thickenings of fasciæ and expansion of tendons which blend with the underlying capsule. The capsule must be large enough to allow the characteristic movements of the joint; consequently, when the bone is moved in any particular direction that side of the capsule is relaxed and thrown into folds. These folds are drawn out of the way either by small special muscles situated beneath those causing the chief movement or by fibres from the deeper surfaces of these latter muscles. In the joints of the arches of the vertebræ, there being no muscles inside the spinal canal, a different arrangement exists for the inner side of the capsule, elastic tissue there taking the place of muscle. The relation of the insertion of the capsule to the line of the epiphysis is important. Although this point is fully considered in the description of the individual joints, it may be here stated that, as a rule, in the long bones, the capsule arises very near the line of the epiphysis.

Fig. 136.

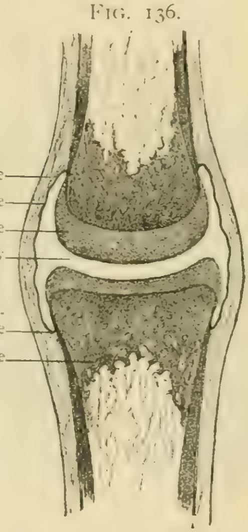


Diagram showing the parts of a typical joint.

The **synovial membrane** which lines the interior of the capsule and other portions of the joint, except the surfaces of the articular cartilages, consists of a delicate connective-tissue sheet, containing many branched and flattened connective-tissue cells. The latter, where numerous, as is the case except at points subjected to considerable pressure, are arranged on the free surface of the synovial membrane as a more or less continuous layer, often spoken of as the endothelium of the synovial sac. Since in many places the layer of connective-tissue elements is imperfect and the component cells retain their stellate form, the cellular investment of the joint-cavity is at best endothelioid, suggesting, rather than constituting, an endothelium. The synovial membrane is in certain places pushed inward by accumulations of fat of definite shape between it and the capsule. It is also prolonged, as the *synovial fringes*,[2] into any space that might otherwise be left vacant in the various movements. They are alternately drawn in or thrust out, according to circumstances. Sometimes pieces of them, or of fibro-cartilage, become detached in the joint, giving rise to much trouble.

The cavity which is found when a joint is opened on the cadaver, with the tissues dead and relaxed, easily suggests a false impression. It is to be remembered that the synovial fluid normally is present in quantity little more than sufficient to lubricate the joint, and that in life all the parts are strongly pressed together so that no true cavity exists. This is well shown by frozen sections.

Certain so-called *intra-articular ligaments*, as the ligamentum teres of the hip, or the crucial ligaments of the knee-joint, are found in the adult, roughly speaking, inside the joint. The sketch of development given above shows that they cannot be truly within the articular cavity. In fact, either they wander in from the capsule, carrying with them a reflection of synovial membrane, or they are the remnants of

[1] Capsula articularis. [2] Plicae synoviales.

the capsules separating two distinct joints which have broken down so as to make a common articular cavity. Such ligaments retain their synovial covering and really lie without the joint-cavity.

Vessels and Nerves.—Important arterial anastomoses surround all the larger joints ; from the larger vessels small branches pass inward to the ends of the bones, to the periphery of the articular cartilages, and to the capsule. The margins of the cartilages are surrounded by vascular loops ; the articulating surfaces are, however, free from blood-vessels. The synovial membrane is usually well supplied with minute branches, a rich net-work being described at the bases of the synovial fringes. The veins form strong plexuses.

Lymphatics are found well developed directly beneath the inner surface of the synovial membrane ; while it is certain that they absorb from the joint, direct openings into the articular cavity have not been demonstrated.

Nerves, presumably sensory and vasomotor, end in the tissues around the synovial membrane. In addition to the Pacinian bodies, which are sometimes very numerous, Krause has described special *articular end-bulbs* outside the synovial membrane surrounding the finger-joints in man.

FIG. 137.

Section through margin of joint, showing articular cartilage and capsule. × 135.

Bursæ[1] are sacs filled with fluid found in various places where friction occurs between different layers or structures. They are sometimes divided into *synovial* and *mucous* bursæ. These varieties are distinct in typical instances, but, since the one passes insensibly into the other, it is doubtful whether this subdivision is warranted. Some bursæ, especially those around the tendons of the fingers, have a true synovial lining reflected over the tendons, and are surrounded by strong fibrous sheaths known as the *thecæ synoviales.*[2] Other bursæ are placed as capsules around a cartilage-coated facet over which a tendon plays. Both the vaginal and capsular varieties may be classed as synovial bursæ. Representatives of the mucous bursæ are those within the subcutaneous tissue where the skin is exposed to friction, as at the elbow and the knee. These bursæ seem little more than exaggerations of the spaces between layers of areolar tissue. The same may be said of some of those among the muscles. The mucous bursæ are provided with more or less of a cellular lining, but the latter is less perfect than in the synovial class. A bursa may be simple or composed of several cavities communicating more or less freely. They often communicate with joints. Their number is uncertain. Many, perhaps most, are present at birth, but new ones may appear in situations exposed in certain

[1] Bursae synoviales. [2] Vaginae mucosae tendinum.

individuals to uncommon pressure or friction, and, under these circumstances, the ones usually present may be enormously enlarged.

Modes of Fixation in Joints.—Ligaments, muscles, atmospheric pressure, and cohesion are the agents for fixation.

Ligaments.—A capsular ligament, pure and simple, has little retaining strength. The accessory ligaments, on the contrary, have great influence. Their arrangement differs with the nature of the joint. Thus, a ball-and-socket joint has thickenings at such parts of the capsule as the particular needs of that joint require. A hinge-joint implies strong lateral ligaments; a rotary joint, some kind of a retaining-band that shall not arrest motion. Sometimes certain ligaments are tense, or nearly so, in every position of the joint, as the lateral ligaments of a hinge-joint. Often a ligament is tense only when a joint is in a particular position, as the ilio-femoral ligament of the hip when the thigh is extended. A strong ligament like the one just mentioned is, when tense, the greatest protection against displacement.

Muscles.—The action of the muscles is of great importance in maintaining the joints in position, in certain instances being the most efficient agency. The constant pull of the muscles keeps the more movable bone closely applied to the more fixed in all positions. Muscles which are nowhere in contact with the joint may exercise this function. The tendons of muscles sometimes act as ligaments, which differ from the ordinary ligamentous bands in that they may be made tense or relaxed by muscular action. Sometimes they are intimately connected with the capsule, at other times distinct from it. Some muscles, whose tendons cross several joints, exercise, by their tonicity, an influence on them all. Thus, the peroneus longus is essential to the maintenance of the transverse arch of the foot. Certain muscles passing over more than one joint exert a ligamentous action on one joint determined by the position of the other. This, however, is more properly discussed in connection with the action of muscles.

Atmospheric Pressure. Much has been written about the action of this agency in holding joints in place. The atmosphere exerts a certain pressure on all bodies, animate or inanimate, and thus tends to compress them. The joints, as parts of the body, are subject to this general influence. It is by no means very efficacious. The shoulder-joint has a capsule long enough to allow very free motion, and consequently too long to hold the humerus in place. This is done chiefly by the muscles. When these are paralyzed the arm falls out of place, atmospheric pressure being inadequate to resist the weight. The most important action of atmospheric pressure is to keep the soft parts closely applied to the bones.

Cohesion is the action of the viscid synovial fluid which tends to hold the surfaces together. It is very feeble, but probably has an appreciable influence in the smaller joints.

Limitation of Motion.—The shape of the joint determines the nature of the movement; its range depends in part on other factors, such as the tension of ligaments or of the tendons of muscles and the resistance of the soft parts.

Motion in True Joints.—It is easy to conceive that an upright rod on the highest point of rather less than half a sphere may slide to the periphery along an indefinite number of lines. This is *angular* motion. The rod on reaching the periphery, or at any point on the way, may travel round in a circle describing the surface of a cone. This is *circumduction*. Finally, without any change of position, the rod may revolve on its own axis. This is *rotation*.

FIG. 138.

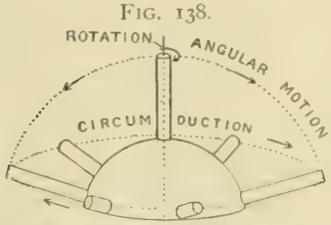


Diagram illustrating different kinds of motion.

Changes of Position of Parts of the Body.—Assuming that the palms are looking forward, angular motion of a limb, or of a part of one, towards the median plane of the body is called *adduction;* the opposite movement, *abduction*. A motion bringing the distal end of a limb bone nearer to the head is called *flexion;* the opposite movement, *extension*. The movements of the ankle and the foot, however, present a difficulty, although the above

nomenclature is generally accepted, since the digital extensor muscles flex and the flexors extend. It is best with reference to the ankle-joint to speak of *plantar flexion* and *dorsal flexion.* *Pronation* in the arm is turning the front of a limb downward ; *supination*, the converse. Thus, when the palm rests upon a table the arm is pronated ; when the back of the hand rests upon the same support the arm is supinated. Reference to the skeleton during these movements will show that pronation is associated with crossing of the bones of the forearm, while during supination they are parallel. These terms should not be applied to motions of the leg. *Rotation* is inward or outward, according as it is towards or away from the median line of the body.

Varieties of True Joints.—The following are the chief kinds of true joints, the nature of the motion being determined by the articular surfaces :

Arthrodia,[1] a *gliding joint* permitting merely a *sliding* between two nearly plane surfaces, as between the articular processes of the vertebræ.

Enarthrosis,[2] a *ball-and-socket joint* permitting *angular* motion in any direction, *circumduction* and *rotation.* The shoulder- and hip-joints are conspicuous examples.

Condylarthrosis,[3] an *egg-shaped joint* permitting *angular* motions more freely on the long axis than on the short one, *circumduction* but (theoretically, at least) no *rotation*, as in the radio-carpal articulations. The imaginary axes for the angular motions lie in the convex bone.

The Saddle-Joint,[4] is a modification of the above, the end of one bone being convex in one plane and concave in another, at right angles to the first, while the other bone is the converse ; thus in one plane one bone is the receiver and in the other the received. The articulation of the trapezium with the first metacarpel bone is an example. The motions in such joints are precisely the same as those of the preceding form. The two imaginary axes are, however, on opposite sides of the joint, each being at right angles to the convex plane of its own bone. It is clear that if the reciprocal curves of the two bones of a saddle-joint coincide, and that if they fit closely, *rotation* is out of the question ; but, in point of fact, that is not the case, for there is no very accurate agreement of the surfaces, and the contained curve is smaller than the containing, so that a certain amount of rotation is possible.[5]

Ginglymus,[6] a *hinge-joint* permitting motion only on a single axis approximately transverse to the long axis of the bone, consequently the moving bone keeps in one plane. The ankle-joint is an example. The inclination of the transverse axis may vary, and one end of the joint be larger than the other. If the course of the revolving bone is that of a spiral around the transverse cylinder the articulation constiutes a *screw-joint*,[7] as the humero-ulnar articulation.

Trochoides,[8] *a pivot-joint* permitting motion only on one axis coincident with at least a part of the long axis of the bone,—namely, *rotation*, as in the atlanto-axial articulation. Should a part of the bone be so bent as to lie outside of the axis, as in the radius, this part undoubtedly changes position ; nevertheless, there is merely rotation, for the change of position is accidental, depending on the shape of the bone, not on the nature of the motion.

Certain complicated joints may combine several of the above forms.

[5] René du Bois-Reymond. Archiv für Anat. u. Phys., Phys. Abtheil., 1895.

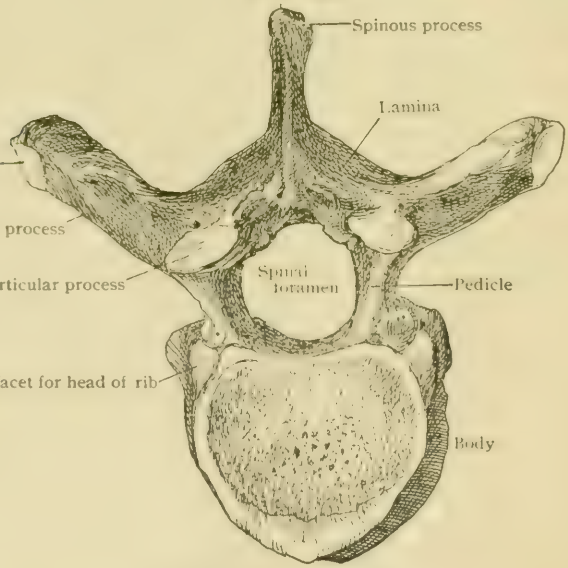
[1] Arthrodia. [2] Enarthrosis. [3] Articulatio ellipsoidea. [4] Articulatio sellaris. [6] Ginglymus. [7] Articulatio cochlearis. [8] Articulatio trochoidea.

THE SPINAL COLUMN.

THE spinal column is the central part of the skeleton. It supports the head, bears the ribs, thus indirectly supporting the arms, and encloses the spinal cord. It gives origin to many muscles, some passing between different parts of the spine, others connecting it with the body. These purposes demand great strength and flexibility. The spine is composed of many pieces united by tough fibro-cartilaginous disks, by which the force of shocks is broken and the great range of movement is distributed among many joints. It is convex behind in the regions of the thorax and pelvis, so as to enlarge those cavities, and has forward convexities in the neck and loins. The numerous prominences which it presents serve for the support of the ribs, the attachment of muscles, and the interlocking of the various pieces. The spinal column is firmly fixed near the lower end between the bones of the pelvis.

The bones composing this column are called *vertebræ*, of which in the adult there are thirty-three or thirty-four in all. They are divided into five groups. The

FIG. 139.



Sixth thoracic vertebra from above.

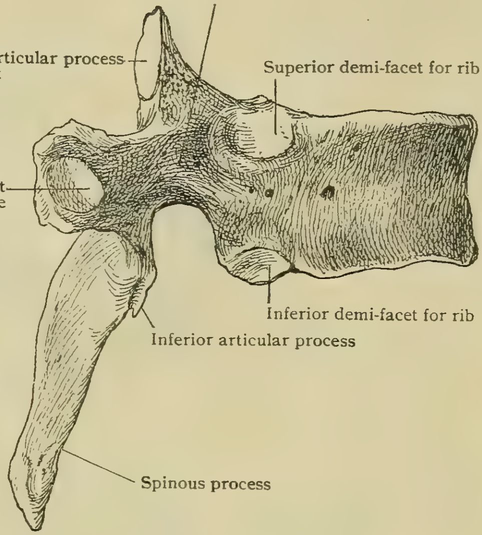
first seven are the *cervical;* the next twelve, which bear ribs, are the *thoracic;* the next five are the *lumbar*, making twenty-four above the pelvis. These are known as the *presacral* vertebræ. The remainder are in the adult united into two bones, the first five forming the *sacrum*, the last four or five the *coccyx*. As many as thirty-eight are seen in the young embryo, but some disappear or are fused.

With the exception of the first two, the *atlas* and the *axis*, which require a separate description (page 119), the vertebræ above the sacrum present the following features, which are common to all, but which are modified in the different regions: (1) a *body*[1] or *centrum;* (2) a *pedicle*[2] springing from the back of the body on either side, supporting (3) the *lamina*,[3] a plate which meets its fellow in the middle line to form an *arch* bounding the *spinal* or *vertebral foramen*[4] for the spinal cord. Each vertebra gives origin to several processes,—namely, (4) a *spinous process*,[5] springing from the point of union of the laminæ; (5) a *transverse process* on each side, projecting outward from the junction of the pedicle and lamina; (6) two *articulating*

[1] Corpus. [2] Radix arcus vertebrae. [3] Arcus. [4] Foramen vertebrale. [5] Processus spinosus. [6] Processus transversus.

processes[1] on each side, one above and one below the lamina, forming true joints with the opposed processes of the neighboring vertebræ ; (7) a *rib* or *costal element*, which in the thoracic region is a separate bone, in the cervical region is a part of the vertebra, and in the lumbar region mingles with the transverse process. The costal element is also represented in the sacrum.

FIG. 140.

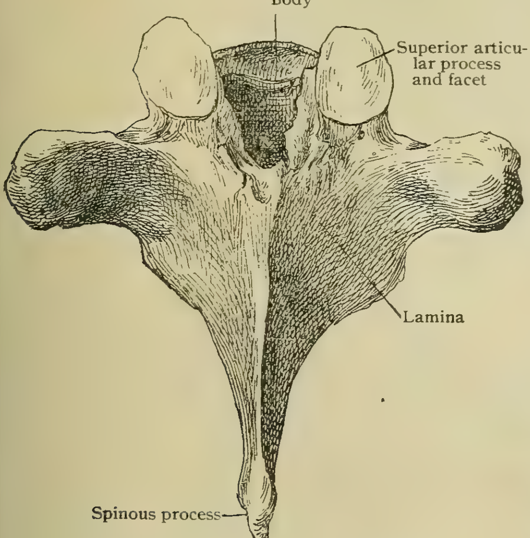


Sixth thoracic vertebra from the side.

Thoracic Vertebræ.—A vertebra from the middle of the thoracic region is described first as intermediate in several respects to the others.

The **body** is but a little broader transversely than from before backward. It is a little deeper behind than in front, thereby helping to form the curve of the spine. The upper and lower borders project a little anteriorly. The upper and lower surfaces, as in all the vertebræ, are rough where the intervertebral disks join them. The posterior surface is concave from side to side, and presents in the middle one or two foramina for the escape of the veins. At the back of the side of the body there is half an articular facet both above and below, which, with the intervening disk, forms an oval, shallow socket for the head of the rib belonging to the lower vertebra.

FIG. 141.



Sixth thoracic vertebra from behind.

The **spinal foramen**, enclosed by the arch, is circular.

The **pedicles**, which are much deeper than thick, arise from the upper half of the body. The superior border rises gradually to the articular process. The inferior border is concave, forming the top of the *notch*,[2] which, when the succeeding vertebra is in place, forms the top of the *intervertebral foramen*,[3] which is wholly behind the lower half of the body.

The **laminæ** are broad, each reaching to the level of those of the next vertebra.

The **spinous process** is long, and points strongly downward, overlapping the one below. It has a narrow under surface which is grooved, and two lateral ones meeting above in a ridge continued from the laminæ. This arrangement of the laminæ and spines completely closes the cavity of the spinal canal. The spinous processes are slightly enlarged at the end for the supraspinous ligament and muscles.

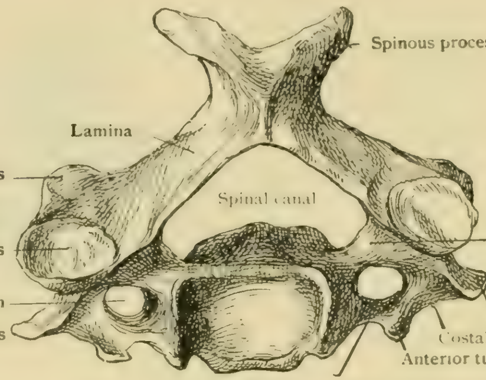
The transverse processes are strong, having to support the ribs. They pro-

[1] Processus articularis. [2] Incisura vertebralis. [3] Foramen intervertebrale.

ject outward and backward, and enlarge at the tip, which anteriorly presents a concave articular surface for the tubercle of the rib, and is rough behind for muscles.

The **articular surfaces** are in two pairs above and below, each pair facing in opposite directions, so that the lower ones of one vertebra meet the upper ones of

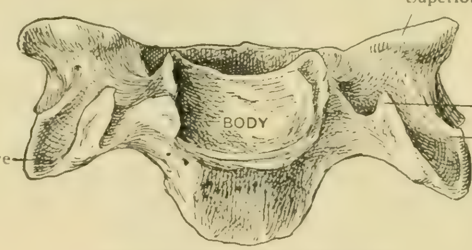
FIG. 142.



Fourth cervical vertebra from above.

the next. Each presents a smooth, roughly oval articular surface. The superior ones face backward, a little outward, and a very little upward; the inferior, conversely, look forward, inward, and slightly downward.

FIG. 143.

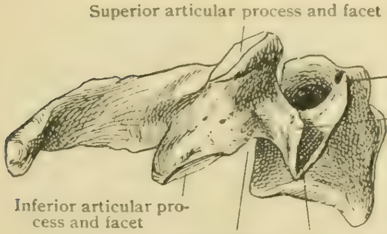


Fourth cervical vertebra from in front.

Cervical Vertebræ.—A typical cervical vertebra is much smaller than the thoracic.

The **body** is decidedly longer from side to side than from before backward. The upper surface is raised at the sides so as to embrace the body next above, and has its front border rounded for the latter to descend over it; for this purpose the lower anterior border is prolonged downward. The height of the body is about the same before and behind.

FIG. 144.



Fourth cervical vertebra from the side.

The **spinal foramen** is triangular, with the greatest diameter transverse.

The **pedicles** are short and light, and extend backward and outward from the body. The notches above and below them are about equal.

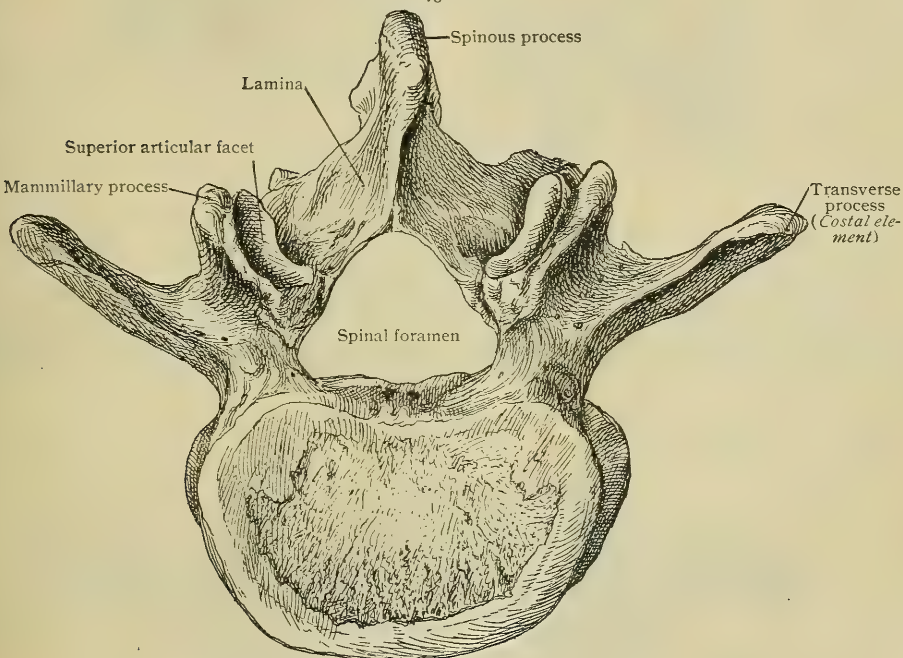
The **intervertebral foramen** is opposite the intervertebral disk, and a part of the bodies of two vertebræ.

The **laminæ** are smooth and do not quite meet those of the next vertebra, unless the head be bent backward.

The **spinous process** projects backward and a little downward. It is short and forked at the end, very often unevenly.

The **transverse processes** are often described as double. The posterior limb, which is the true transverse process, projects outward and somewhat forward from the junction of the pedicle and lamina, and ends in a flattened, nearly vertical projection, the *posterior transverse tubercle*. The anterior limb, a vertical plate springing from the side of the body and extending outward, ends in the *anterior transverse tubercle*. This limb is the shorter of the two and its tubercle the larger. The limbs are connected by a concave plate or bone, slanting slightly outward, which forms the floor of a gutter[1] in which the spinal nerve lies, and which represents the costal element. A round hole, the *transverse foramen*, for the vertebral artery and veins, lies internal to this plate ; the artery usually does not pass through the foramen of the seventh vertebra. Since the scalenus anticus muscle springs from the anterior

FIG. 145.



Third lumbar vertebra from above.

tubercles and the scalenus medius from the posterior ones, on leaving the spine the spinal nerves pass between these muscles.

The **articular processes** are placed at the outer ends of the laminæ ; the upper face upward and backward, the lower forward and downward.

Lumbar Vertebræ.—A typical lumbar vertebra is very much larger than the others.

The **body** is broad from side to side, the upper and lower borders projecting especially at the sides. The posterior surface is slightly concave and presents two large venous openings.

The **spinal foramen** is three-sided, with a transverse diameter but slightly exceeding the antero-posterior.

The **pedicles** are short and strong, diverging only slightly. They are very nearly on a level above with the top of the body, so that there is a small notch above and a large one below.

The **laminæ** are broad at the sides, but less so near the mid-line, so that in this

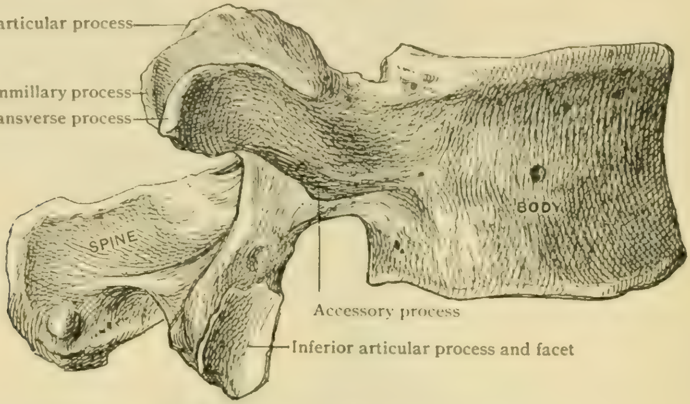
[1] Sulcus n. spinalis.

region there is a large opening into the spinal canal. A considerable part of the arch is lower than the body.

The **spinous process** is a flat projection extending nearly straight backward, with two lateral surfaces and a superior, inferior, and posterior border. The last is rough and thickened below, with occasionally a tendency to become bifid.

The **transverse processes,** which are solely for muscular attachments, and

FIG. 146.

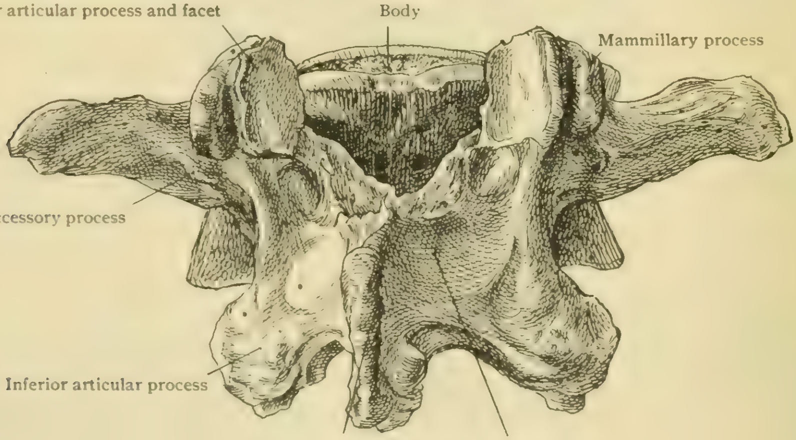


Third lumbar vertebra from the side.

therefore not heavy, project outward and somewhat backward. They are thin, having an anterior and a posterior surface and a blunt end.

The **articular processes** are large, very nearly vertical, and curved. The superior, facing somewhat backward but chiefly inward, are concave and embrace the inferior ones of the vertebra above, which are convex, and face in the opposite direction.

FIG. 147.



Third lumbar vertebra from behind and the side.

The **mammillary processes** form on either side a rounded lateral projection on the posterior border of the superior articular process. Additional tubercles, the **accessory processes,** appear as inconspicuous elevations at the junction of the posterior border of the transverse with the superior articular processes. The details and the morphological significance of the mammillary and the accessory processes are discussed later (page 123).

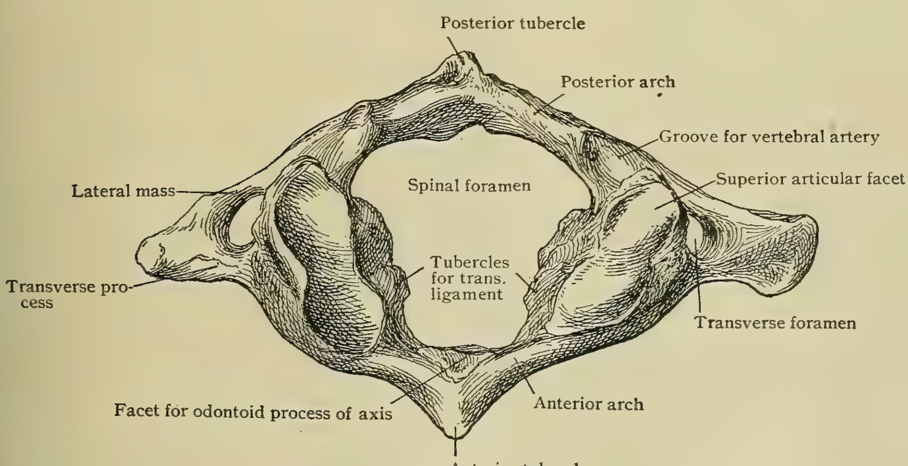
The chief points of difference between typical vertebræ of the three presacral groups may be tabulated as follows :

	Cervical.	Thoracic.	Lumbar.
Body.	1. Broad.	Diameters nearly equal; concave behind.	Broad.
	2. Upper surface with raised sides and rounded anterior border.	Plane.	Plane.
	3. No facets.	Costal semifacets.	No facets.
Spinal Foramen.	Triangular, with greatest diameter transverse.	Nearly circular.	Triangular, with diameters nearly equal.
Pedicles.	Notches above and below nearly equal.	Rising from top of body; great notch below.	Small notch above, great one below.
Laminæ.	Narrow, with spaces between.	Broad ; no spaces between.	Extending downward; large spaces between.
Transverse Processes.	Double foramen at root ; two tubercles.	Strong, with articular facet.	Slender.
Superior Articular Surfaces.	Nearly plane ; face upward and backward.	Plane, vertical ; face nearly backward.	Concave, vertical ; face chiefly inward.

PECULIAR VERTEBRÆ.

Certain vertebræ differ more or less markedly from the type of their respective groups ; in some cases, as the upper two cervical vertebræ, these variations result in conspicuous modifications ; in others, as the lower thoracic, the peculiarities are less pronounced. Although the most noteworthy differences are here given, the reader

Fig. 148.



The atlas from above.

is referred to the discussion of the gradual changes which occur in passing from one region to the other (page 122) for a more complete account of the modifications to be observed.

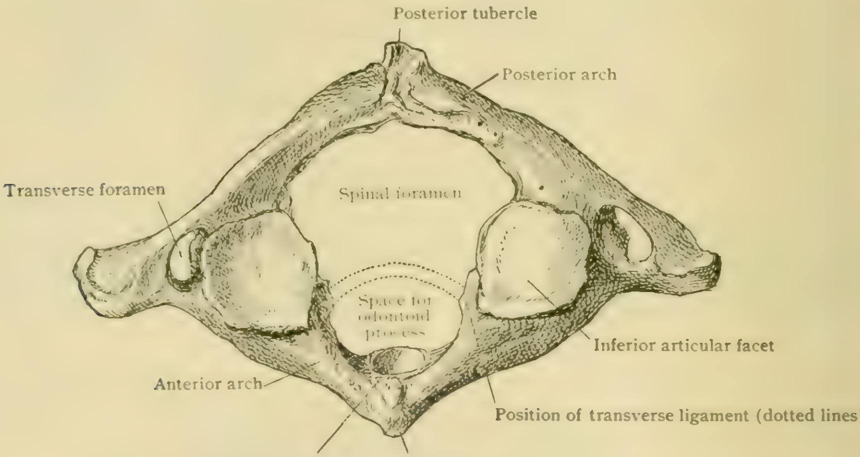
The **first** and **second cervical vertebræ**, known as the *atlas* and *axis*, constitute a special apparatus for the security and movements of the head. The key to

the arrangement is that the part which in the ordinary process of development should become the body of the atlas is instead fused with the body of the axis.

The **atlas**, having no body, consists of two *lateral masses*, connected by a short *anterior arch* and a long *posterior* one. The *lateral masses* present the *articular facets* on their lower and upper surfaces. The inferior look downward and slightly inward, and are very slightly concave from side to side. The superior facets are oval concavities the backs of which are strongly raised from the surface. Their long axis runs forward and inward, the outer wall being decidedly higher than the inner. The articular facet narrows at the middle, and is often marked by a transverse ridge at this point ; rarely it is divided into two parts. The articular surfaces of the two sides sometimes very nearly correspond with parts of the surface of a single imaginary sphere.

Their variation in all respects is great. Thus, Macalister[1] finds in one hundred bones that the distance between the front ends of the two facets varies from ten to twenty millimetres, being usually from fifteen to twenty millimetres, and that the hind ends are from thirty-two to fifty millimetres apart, the greater number being separated from thirty-five to forty millimetres. The angle formed by the intersec-

FIG. 149.



The atlas from below.

tion of the prolonged axes of the articular facets ranges from thirty-two to sixty-three degrees. Each lateral mass presents a rough tubercle on the inner side between which passes the transverse ligament holding the odontoid process close against the anterior arch. The *anterior arch* is compressed from before backward. It presents the *anterior tubercle* in front in the median line, and behind has a slightly concave articular facet for the odontoid process. The *posterior arch* bounds the spinal canal behind. The transverse ligament, confining the odontoid process, bounds the spinal canal in front, and, being in place, the transverse diameter of the canal is the longer. The place of the spinous process is taken by the *posterior tubercle*. The *transverse processes* extend farther out than any in the cervical region. Each ends in a single flattened knob with a surface slanting downward and forward. Bifurcation is rare. The *transverse foramen* is at its base ; from the foramen a *groove* for the vertebral artery crosses the root of the posterior arch and winds round behind the raised border of the articular surface. This groove is occasionally bridged over by a little arch of bone extending from the edge of the articular surface either to the transverse process or to the posterior arch.

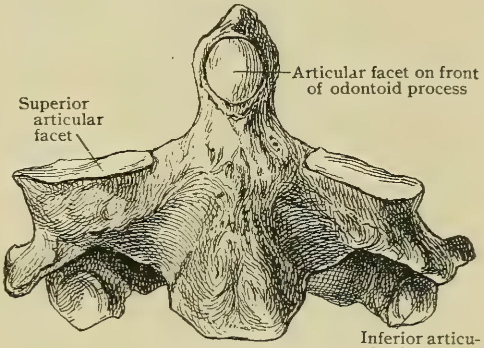
Variations.—The atlas may be fused with the occipital bone in various ways; this may occur by the pathological destruction of the joint, or the arch, or a

[1] Journal of Anatomy and Physiology, vol. xxvii., 1893.

part of it, may be fused with the skull around the foramen magnum. Such union may be partial or complete, and is usually associated with an imperfect development of the atlas, especially on one side. There is reason to regard such cases as congenital. The transverse process and the paroccipital process of the occipital bone may be connected by bone.

The **axis**[1] differs less from the other cervical vertebræ ; seen from below it presents no essential peculiarity. The *body* is very long even without the odontoid process (the separated body of the atlas) which surmounts it. The *odontoid*,[2] a cylindrical process lower behind than in front, ends above in a median ridge, on either side of which is a rough, slanting surface for the origin of the check ligaments connecting it with the skull. It bears an oval articular facet in front, resting against one on the atlas, and a smaller facet behind at a lower level which forms part of a joint with the transverse ligament. The *laminæ*, instead of being plates, are heavy and prismatic, each with a rather sharp upper edge, which, meeting its fellow, forms a ridge on the spine. The *spinous process* is heavy, projecting considerably beyond the third. It varies greatly in length and in degree of bifurcation. The *transverse process* is small ; the anterior tubercle is a mere point or altogether wanting. The *transverse foramen* is replaced by a short canal, so curved that its upper opening looks almost outward. The *superior articular surfaces* are approximately circular facets on the upper surface of the body instead of on the arch, as are all below ; they look upward and a little outward. Although nearly plane, they present a very slight antero-posterior convexity.

FIG. 150.

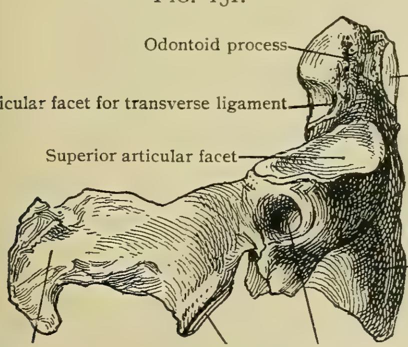


The axis from in front.

The **seventh cervical** vertebra, called *vertebra prominens* on account of its long, knobbed spine, rather resembles the upper thoracics. The *transverse foramen* is smaller than those above it, and the *anterior tubercle* of the transverse process is particularly small and near the body.

The **first thoracic** vertebra has the sides of the upper surface somewhat raised at the roots of the pedicles. It has a *complete facet* for the head of the first rib and a half-facet at the lower border of the body. Sometimes the former is imperfect, being completed on the intervertebral disk. The facet on the transverse process is smaller and less concave than the ones following ; sometimes it is even convex.

FIG. 151.



The axis from the side.

The **ninth thoracic** vertebra has no half-facet below.

The **tenth thoracic** vertebra has a nearly complete facet above and none below.

The **eleventh thoracic** vertebra has a complete facet on the body and none on the transverse process, which is small.

The **twelfth thoracic** vertebra has a complete facet a little above the middle of the body. The transverse process is broken up into the three tubercles. The lower articular facets face outward. The spine is of the lumbar type.

[1] Epistropheus. [2] Dens.

The **fifth lumbar** vertebra is much higher in front than behind. The transverse process is broad at the base, springing in part from the body ; the spine is relatively small.

DIMENSIONS OF VERTEBRÆ.

(The measurements are given in centimetres.)

Vertebræ.		Height of Front of Bodies. (Dwight.)	Height of Front of Bodies. (Anderson.[1])	Height of Back of Bodies. (Anderson.)	Transverse Diameter. (Anderson.)	Antero-Posterior Diameter. (Anderson.)	Spread of Transverse Processes. (Dwight.)
		Twenty spines.	Thirty spines.	Thirty spines.	Fifty-three spines.	Twenty-eight spines.	Fourteen spines.
Cervical . . .	2	. .	1.9	.	1.9	1.5	5.5
" . . .	3	1.2	1.2	.	1.9	1.5	5.4
" .	4	1.2	1.2	. .	2.1	1.5	5.4
"	5	1.2	1.2	. .	2.3	1.6	5.7
" . . .	6	1.1	1.1	. .	2.5	1.7	5.9
" .	7	1.3	1.3	. .	2.7	1.8	7.2
Thoracic . . .	1	1.5	1.4	1.5	2.7	1.7	7.6
" . .	2	1.7	1.6	1.7	2.8	1.7	7.1
" . .	3	1.7	1.7	1.8	2.6	1.9	6.3
" . . .	4	1.7	1.7	1.9	2.6	2.2	6.3
"	5	1.7	1.7	2.0	2.5	2.4	6.4
"	6	1.8	1.8	1.9	2.7	2.5	6.4
" .	7	1.8	1.8	2.0	2.8	2.6	6.3
" . . .	8	1.8	1.8	2.1	3.0	2.8	6.3
"	9	1.9	1.9	2.1	3.1	2.9	6.2
" .	10	2.1	2.1	2.2	3.4	2.9	5.8
" .	11	2.1	2.1	2.4	3.6	2.9	5.2
"	12	2.3	2.3	2.5	4.0	3.0	4.7
Lumbar . .	1	2.4	2.4	2.6	4.2	2.9	7.3
" .	2	2.5	2.5	2.7	4.4	3.1	8.0
" . . .	3	2.5	2.6	2.7	4.7	3.6	9.0
" . . .	4	2.5	2.6	2.6	4.8	3.3	8.5
" . . .	5	2.6	2.7	2.2	5.2	3.6	9.1

GRADUAL CHANGES FROM ONE REGION TO ANOTHER.

Bodies.—The height of the bodies increases as we descend the spine, very gradually in each region but rather rapidly at the junction of two regions, as shown in the table. The first two lumbars, like those above them, are rather deeper behind than in front, but the reverse is true of the last two, and especially of the fifth, in which the difference is considerable. The breadth of the bodies increases to the first or second thoracic, then dwindles to the fourth or fifth, and then again increases to the sacrum. The elevation at the sides of the upper surfaces of the bodies of the cervical vertebræ diminishes in the lower part of that region ; in the seventh it is limited to near the root of the pedicle. The same condition is found in the first thoracic vertebra and to a slight extent in the next two. The downward prolongation of the front of the body of a cervical vertebra is slight in the lower part of the neck. The first thoracic has an entire facet for the head of the first rib near the top of the body and a part of one at the lower border for a portion of the head of the second. As a rule, in the thoracic region the head of each rib rests in a facet on two vertebræ and the intervening disk, the lower vertebra contributing more of the joint than the upper, and corresponding with the rib in name. Thus, the head of the fourth rib lies between the third and fourth thoracic vertebræ, and its tubercle rests on the transverse process of the fourth. Towards the lower part of the region the heads have a tendency to take a lower relative position on the column coincidently with the increase in size of the bodies. The head of the tenth rib usually rests wholly on the body of the tenth vertebra or on it and the disk above, conse-

[1] Journal of Anatomy and Physiology, vol. xvii., 1883. Anderson states that the vertical diameters of the front and back of the cervical vertebræ are generally the same ; hence, probably, he thought it needless to give the posterior measurements. The close correspondence of his anterior measurements with those of the author is very striking.

quently the ninth vertebra has no half-facet below. The tenth has a nearly or quite complete facet at its upper border, the eleventh has a complete one rather below the top of the body, and the twelfth has a complete facet nearly half-way down. At the ninth or tenth the facet begins to leave the body and to travel backward onto the root of the pedicle.

When the body is seen from above or below in certain parts of the thoracic region the front curve is flattened on the left by the pressure of the aorta. This compression usually is first seen at the top of the fifth thoracic, and is traceable downward for a few vertebræ, sometimes as far as the lumbar region. The depression gradually passes from the side to the front as it descends the spine.

The Transverse Processes.—As shown by the table, the spread of the transverse processes increases greatly at the junction of the cervical and the thoracic regions, falls rapidly to the third thoracic, remains stationary to the tenth, falls to the last thoracic, the narrowest point, and then gains at once, reaching the maximum at the third lumbar. The anterior tubercles of the transverse processes of the cervical region increase to the sixth, which is the *tubercle of Chassaignac*, who taught that the carotid artery can be compressed against it, the force being directed backward and a little inward. The anterior limb of the transverse process of the seventh vertebra is very short, and its tubercle is usually rudimentary. It is distinctly in series with the slight elevation of the socket for the head of the first rib often seen on the first thoracic vertebra. The piece of bone between the tubercles, forming the floor of the gutter for the spinal nerve, is much longer and more anteriorly placed in the seventh than in those above it. It is this piece connecting the two tubercles that is the *true costal element* in the neck. The so-called anterior limb of the transverse process with the tubercle on it is in line, not with the ribs but with the anterior tubercle called the *processus costarius*. The articular facet on the transverse process of the first thoracic is shallow, often convex, and faces a little downward. That of the second, at which point the processes slant more backward, is concave and somewhat overhung above ; this is seen in the two or three following, after which the facets grow smaller, more shallow, and look upward as well as forward. As the eleventh rib has but a rudimentary tubercle and the twelfth none at all, there is no facet on the transverse process of the last two thoracic vertebræ. The latter process of the eleventh is small, and that of the last broken up into three tubercles, (1) the *superior* or *mammillary*, rising from the posterior surface ; (2) the *accessory* or *inferior*, pointing downward ; (3) the *external*, a knob, the smallest of the three. The latter two represent the transverse process of the upper thoracic vertebræ. All three tubercles are usually to be recognized on the eleventh thoracic, although the accessory tubercle is usually not seen higher up. The knobs for muscular attachment on the backs of the thoracic transverse processes are evidently in line with the mammillary tubercles, rudiments of which are found in a large part of the thoracic region. In the lumbar region they are found on the side of the superior articular processes, growing smaller in the lower vertebræ, and being lost in the fifth.

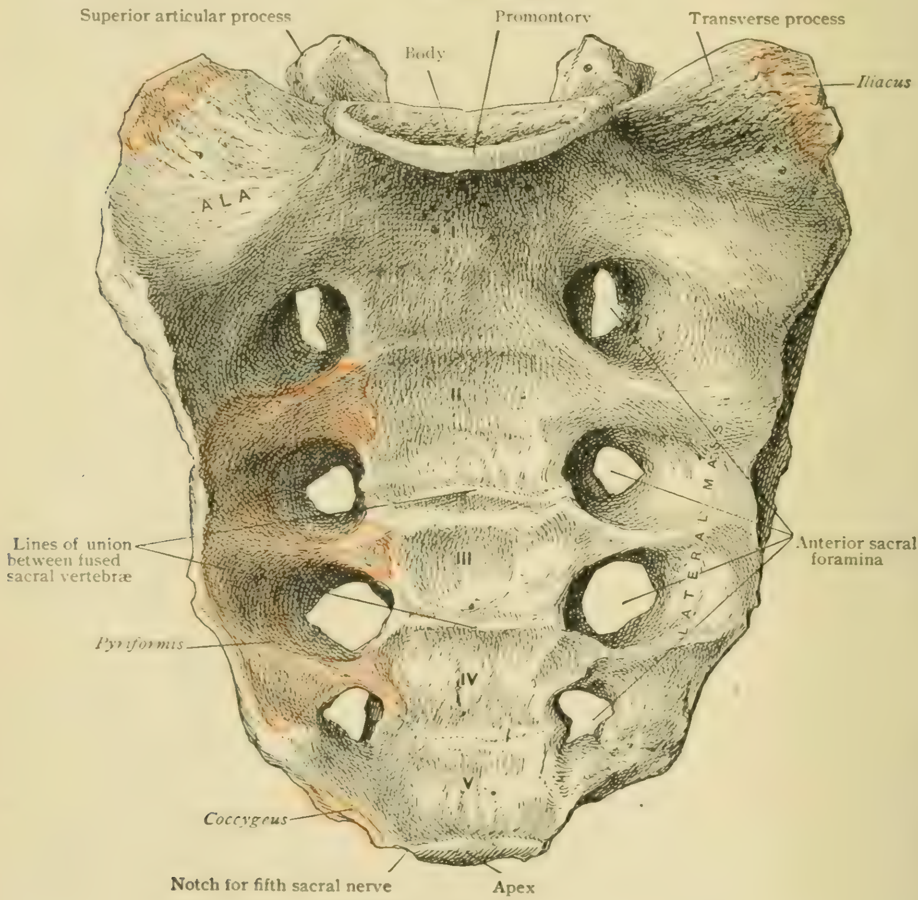
The lumbar transverse processes increase in length to the third, which is the longest, unless it be equalled by the fifth. That of the fourth is peculiar in being shorter and lighter than its neighbors. It usually has a rather triangular outline, owing to the lower border approaching the upper near the tip, and also arises farther forward,—*i.e.*, nearer the side of the pedicle than those above it. The fifth is much heavier and arises from the side of the body as well as from the pedicle, so that its anterior portion is evidently in series with the costal element developed in the sacrum, described in connection with that bone. The process which, in accordance with general usage, has been called the lumbar transverse process, is clearly in direct continuation with the line of the ribs. This is particularly striking in certain cases in which it is not easy to determine whether there is a thirteenth rib, or whether this process is to be considered as free in the first lumbar. The accessory tubercle, which can be made out in the lumbar region, and is particularly large in the lower vertebræ, is in line with the ends of the transverse processes of the thorax. Thus the so-called lumbar transverse process represents at its root both a rib and the accessory and transverse tubercles, and beyond its root a rib only. This is especially marked in the broad process of the fifth lumbar, which springs from the side of the body

as well as from the pedicle. The homologies of the costal elements are shown in Fig. 158.

The Spinous Processes.—These are short and bifid in the third, fourth, and fifth cervical vertebræ; longer and usually not forked in the sixth; and longer, larger, and knobbed in the seventh. The type is that of the last mentioned in the upper thoracic, only the spine is a little longer, stronger, and more slanting. At about the fourth a sudden change occurs: the process becomes longer, sharper, and more descending. At about the tenth it shortens again, points more backward, and approaches the lumbar type, which is generally reached in the last thoracic. The spine of the last lumbar is usually much smaller than those above it.

The Articular Processes.—The change from the cervical type to the thoracic is gradual, but that from the thoracic to the lumbar occurs suddenly at the junction of those regions. The inferior processes of the last thoracic face outward. Not infrequently the change occurs a space higher, but rarely one lower. Occasionally the facets between the regions face in an intermediate direction. Sometimes the change is normal on one side and not on the other.

FIG. 152.



The sacrum, anterior surface.

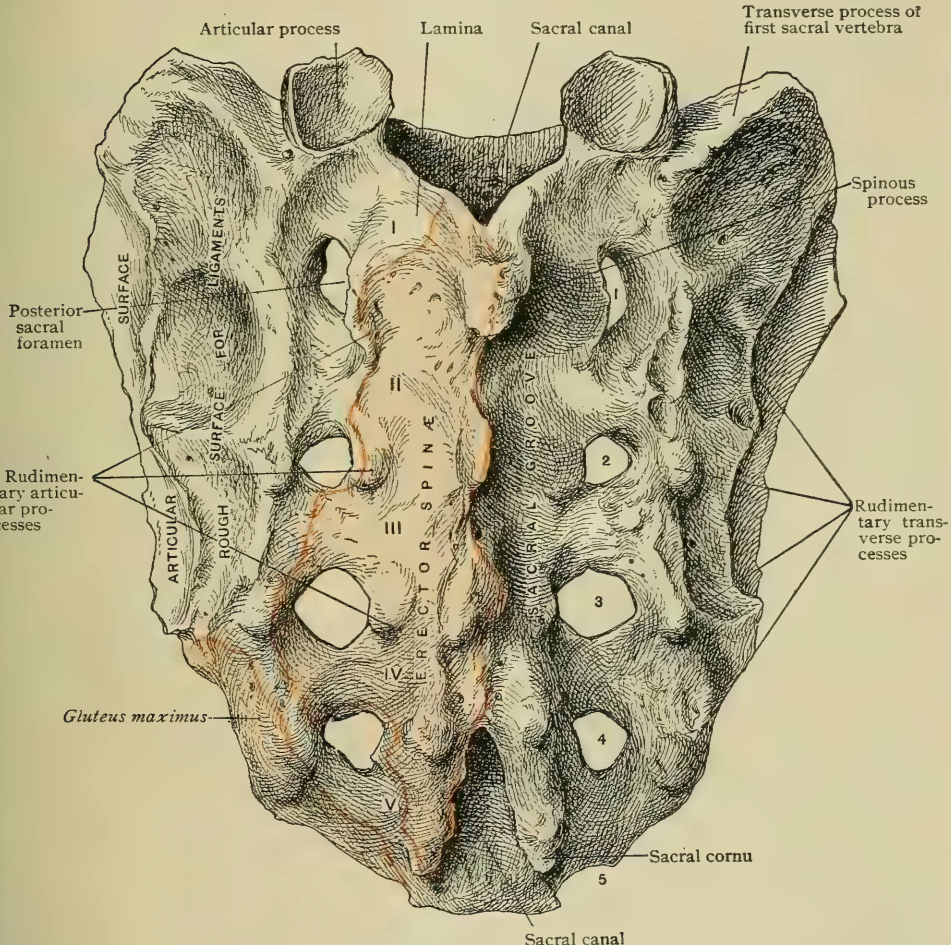
THE SACRUM.

This bone[1] is composed of five fused and modified vertebræ, of which the three upper support the pelvis laterally. The vertebræ decrease very much in size from above downward, the lower being bent strongly forward. The first vertebra is comparatively but little changed; the last consists of little more than the body. The

[1] Os sacrum.

essential modification, besides the fusion, is the occurrence of the *lateral masses*,[1] representing transverse processes and ribs, which, springing from the bodies and arches, are connected with the innominate bones by joints and ligaments. The sacrum has an upper surface, or *base*, a lower, or *apex*, and a front, back, and two lateral surfaces. The base has above a rough space representing the end of the body of a vertebra to which the last lumbar disk is attached. It is raised a little from the bone and forms an acute projecting angle with the front surface, known as the *promontory* of the sacrum, an important landmark in midwifery. Behind the body of the first sacral vertebra is the triangular orifice of the *sacral canal*, the

FIG. 153.



The sacrum, posterior surface.

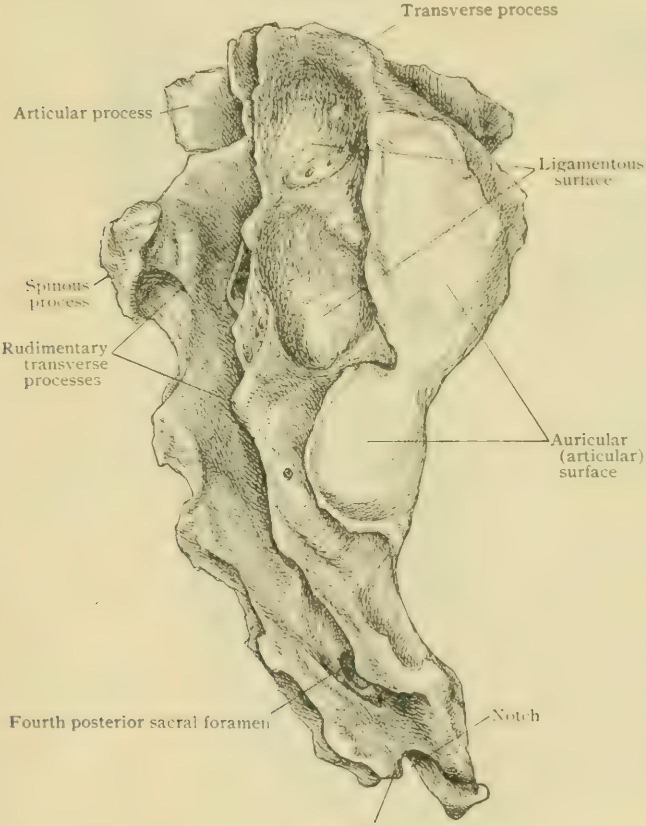
transverse diameter of which is the greater. The *articular process*, springing from the side of the arch, is vertical, the concave facet facing backward and inward. The upper surface of the lateral mass, the *ala*, springs from the side of the body and the pedicle, expanding into a broad area, and is bounded in front by an ill-marked, rounded border which separates it from the anterior surface and curves forward; behind by a shorter border curving backward, on which the auricular process rests; and outside by an irregular convex border. The latter may often be subdivided into two parts: an anterior, running pretty nearly forward and backward and corresponding to the top of the auricular surface, and a posterior, running backward

[1] Partes laterales.

and inward. Thus the sacrum is broader before than behind. The *apex* is nothing but the under side of the body of the very small fifth sacral vertebra.

The **anterior surface** is a triangular concavity formed by the bodies and lateral masses of the five sacral vertebræ. It has a double row of four openings the *anterior sacral foramina*, one on each side of the ridges, representing the ossified disks connecting the bodies of the fused sacral vertebræ. The sacral nerves, like the other spinal nerves, divide into an anterior and a posterior division on leaving the spinal canal; in the case of the sacral nerves, however, this takes place inside the bone, the anterior divisions escaping by these foramina. The bodies and the foramina grow smaller from above downward, and the latter are nearer together. A transverse depression across the body of the third vertebra usually marks a rather sudden change in the curvature of the anterior surface. The irregular outline of the lateral borders may be divided into two parts: the upper, rather concave, ends below in a little point on a level with the third vertebral body, and represents the extent of the articular surface. Below this the border slants downward and inward until opposite the lower part of the fifth sacral segment, when it suddenly turns inward, forming a *notch* over the anterior division of the fifth sacral nerve, which emerges between it and the coccyx.

FIG. 154.



The sacrum, lateral view.

The **posterior surface** is composed of the fused *laminæ* and their modifications. The upper borders of the first laminæ slant downward, and below their junction is a well-marked *spine*.[1] Below this the laminæ of the sacral vertebræ are fused and the spines small. The laminæ of the fifth sacral never join, and those of the fourth frequently do not, thus leaving the lower end of the canal uncovered. The laminæ that do not meet end in tubercles each representing one-half of a spinous process. The lowest two project downward at the sides of the open canal, and are called the *sacral cornua*. Four *posterior sacral foramina* for the exit of the posterior divisions of the nerves appear on each side of the laminæ. Outside of these are some irregular tubercles representing the *transverse processes*,[2] and internal to the first three foramina are tubercles in line with the *articular processes*.[3]

The **lateral surface** begins just outside of the transverse tubercles. It is broad above, but below the third vertebra is merely a line. The upper part is divided into two portions: the front one is the *auricular surface*, from a slight resemblance to an ear, which joins, by fibro-cartilage, the corresponding surface on the ilium. It is broader above than below, convex in front, indented behind, with

[1] Crista media. [2] Cristae laterales. [3] Cristae articulares.

slightly raised edges and a rough, irregular surface. The auricular surface is formed chiefly by the lateral mass of the first sacral (*vertebra fulcralis*, as having the most to do in supporting the pelvis), to a less extent by that of the second, and very little by that of the third. Behind this articular portion lies the rough ligamentous surface, which slants backward and inward, and affords origin for the posterior sacro-iliac ligaments.

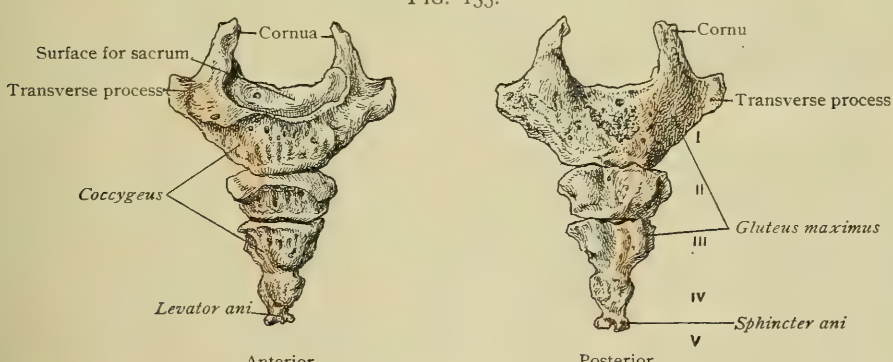
Differences depending upon Sex.—The female sacrum is relatively broader than the male. The *sacral index*, or the ratio of the breadth to the length $\left(\frac{100 \times \text{breadth}}{\text{length}}\right)$, is 112 for the white male and 116 for the female. Such a rule is, however, not absolute, there being many doubtful cases, but a narrow sacrum is almost invariably male. Another, and very reliable, guide, especially in conjunction with the first, is the curve. There are contradictory statements among authors, but the truth is, as originally shown by Ward, that the male sacrum is the more regularly curved, while the anterior surface of the female bone runs in nearly a straight line from the promontory to the middle of the third piece and then suddenly changes its direction.

Variations.—The sacrum often consists of six vertebræ. Such a one may be recognized even when the lower part is wanting, so that the vertebræ cannot be counted. If a line across the front, connecting the lowest points of the auricular surfaces, passes below the middle of the third sacral, the sacrum is of six pieces ; if above, of five.[1] Sacra consisting of only four vertebræ are rare.

THE COCCYX.

This bone is composed of four or five[2] flattened plates representing vertebral bodies. It is an elongated triangle with the apex below. The *base*, joined by fibro-cartilage to the apex of the sacrum, is oblique, the posterior border being higher than the front, so that the coccyx slants forward from the sacrum. The *anterior surface* of the coccyx is, moreover, very slightly concave. The *first vertebra* consists of a thin *body*, about twice as broad as long, from the back of which on each side the rudiment of an arch extends upward as a straight process, the *coccygeal cornu*, which

FIG. 155.



The coccyx.

overlaps the back of the body of the last sacral vertebra and joins the sacral cornu. A short lateral projection from the side of the body represents the *transverse process;* perhaps the *costal element* also. On the upper border of this process, at its origin, is a *notch*, which usually forms a foramen with the sacrum for the anterior division of the fifth sacral nerve. Very faint rudiments of these two pairs of processes are sometimes to be made out on the second vertebra, which is much smaller than the first, but also broad and flat. The succeeding ones are much smaller and ill-defined. Constrictions on the surfaces and notches on the edges mark the outlines of the

[1] Bacarisse : Le sacrum suivant le sexe et suivant les races. Thèse, Paris, 1873.

[2] According to Steinbach, there are five in man and four or five in woman. Die Zahl der Caudalwirbel beim Menschen. Inaugural Dissertation, Berlin, 1899.

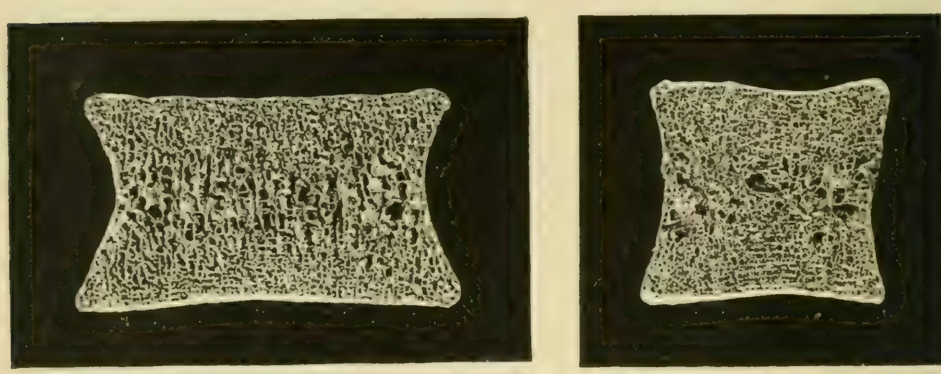
original pieces, which become less and less flat and more and more rounded. It is rare to see more than four distinct segments, but very often the last is somewhat elongated and shows signs of subdivision. It is not uncommon for the first piece to remain separate, neither fusing with the sacrum nor the next coccygeal plate.

STRUCTURE OF THE VERTEBRÆ.

The shell of compact bone forming the surface is everywhere very thin. The general plan of the internal spongy bone is one of vertical plates which in a frontal section (Fig. 156, *A*) are bowed somewhat outward from the middle of the bone, and of transverse plates connecting them near together at the ends and farther apart in the middle third where larger spaces occur. The strongest plates spring from the pedicles and diverge through the bone, joining, probably, for the most part the horizontal system. In the sacrum the same general plan prevails, but in addition there are series of plates, mainly horizontal, in the lateral parts ; those from the first sacral are the most important.

FIG. 156.

A *B*



Frontal (*A*) and sagittal (*B*) sections of body of lumbar vertebra, showing the arrangement of the bony lamellæ. Natural size.

DEVELOPMENT OF THE VERTEBRÆ.

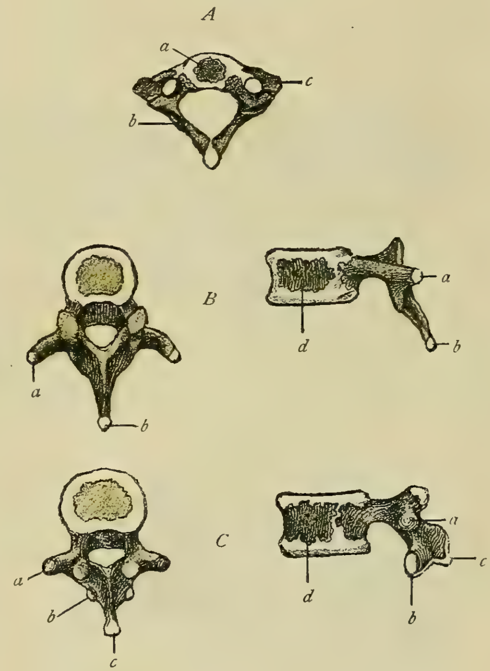
Presacral Vertebræ.—These vertebræ ossify from three *chief centres* and at least five *accessory* ones. The median one of the three chief centres forms the greater part of the body ; while the other two, one appearing in each pedicle, form the postero-lateral part of the body, the arch, and the greater part of the processes. The oblique *neuro-central sutures* separate the regions of these centres. The lateral centres of the upper thoracic and the cervical vertebræ appear first. It is usually taught that they appear in the sixth or seventh week of fœtal life, but Bade[1] with the Röntgen rays found no sign of them at eight weeks. The point is unsettled. The first median centres to appear are those of the lower thoracic and the upper lumbar vertebræ. In this region and below it the median centres precede the lateral ones ; in the upper part of the spine the growth is much more vigorous in the lateral centres. The median centres of the cervical vertebræ appear in order from below upward. The upper ones (judging from Röntgen-ray work and from transparent fœtuses) sometimes have not appeared as late as the sixth month, although we have seen them towards the close of the third.

At birth the upper and lower ends of the bodies are still cartilaginous, but the arches are well advanced in ossification, although bone does not cross the median line until some months later. The transverse processes of the thoracic vertebræ are farther advanced than those in other regions. The spines are still cartilaginous. The neuro-central suture is lost at from four to six years, disappearing first in the

[1] Arch. für Mikros. Anat., Bd. lv., 1899.

lumbar region. The tips of the spinous and transverse processes develop from centres which appear about puberty and fuse about the eighteenth year. A thin epiphyseal disk, covering the upper and lower surfaces of each body, grows from a centre seen about the seventeenth year, and joins by the twentieth, the line of union persisting a year or two longer. The mammillary processes of the lumbar region arise from separate centres ; so do also the costal elements of the sixth and seventh cervicals, and sometimes that of the first lumbar. In cases in which this costal element of the seventh cervical remains free there is a cervical rib and no transverse foramen ; exceptionally in these cases a foramen persists. According to Leboucq,[1] the development of the anterior limb of the transverse process of the cervical vertebræ is more complicated than is usually taught. There is a slight outward projection from the ventral side of the body representing the prominence for the head of the rib to rest upon ; this grows outward and meets a growth from the transverse process that grows inward like a hook. This inward growth represents what we commonly call the costal element of a cervical vertebra, but there may be also a separate ossification representing an actual rib,—namely, a small piece of bone on the ventral aspect of the tip of the transverse process of the seventh cervical vertebra. When a separate ossification occurs in this region in the fifth or sixth vertebra, it is situated still more externally than in the seventh, and forms the floor of the gutter between the anterior and the posterior tubercles, which is the true costal element. It is probable that in certain cases of cervical ribs accompanied by a transverse foramen, the latter is enclosed by the hook-like process from the transverse process meeting the growth from the body of the vertebra, and that the rib coming from the separate ossification lies anteriorly to it and distinct from it. At birth the lumbar articular processes resemble the thoracic. The type changes in early childhood.

FIG. 157.



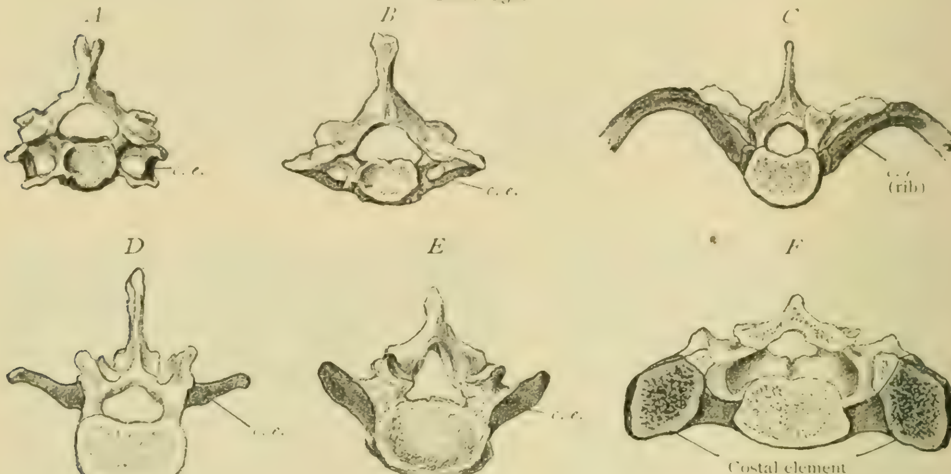
Ossification of the vertebræ. *A*, cervical vertebra at birth ; centres for body (*a*), neural arches (*b*), and costal element (*c*). *B*, dorsal vertebra at two years ; cartilaginous tips of transverse (*a*) and spinous (*b*) processes ; *d*, centre for body. *C*, lumbar vertebra at two years ; position of additional later centres for various processes indicated (*a*, *b*, *c*) ; *d*, centre for body.

The Sacrum.—Each sacral vertebra has the three primary centres of the others, the median ones appearing before the lateral of the same vertebra. Probably the median centres of the first three appear first and then the lateral ones of the first vertebra ; data, however, are wanting for a definite statement. The time of the first appearance of ossification in the sacral vertebræ is very variable ; probably the earliest median centres appear about the beginning of the fourth month and the lateral ones some weeks later. In a skiagraph of a fœtus estimated to be about three and a half months old the median centres of the upper three vertebræ and the lateral ones of the first are visible. This is, perhaps, earlier than the rule. Little progress in ossification of the last two sacrals takes place before birth. The lateral centres join the median, in the lower vertebræ, during the second year ; in the upper ones, three or four years later. In the upper three vertebræ a centre appears outside the anterior sacral foramen, from which a part of the lateral mass is developed.

[1] Mémoires couronnés, etc., Acad. Royale des Sciences de Belgique, tome lv., 1896.

This represents a *costal element* which fuses with the front of the pedicle. Those of the first two sacrals appear shortly before birth (Bade). The line of union can still be seen at seven years on the top of the first vertebra. The time at which the laminæ

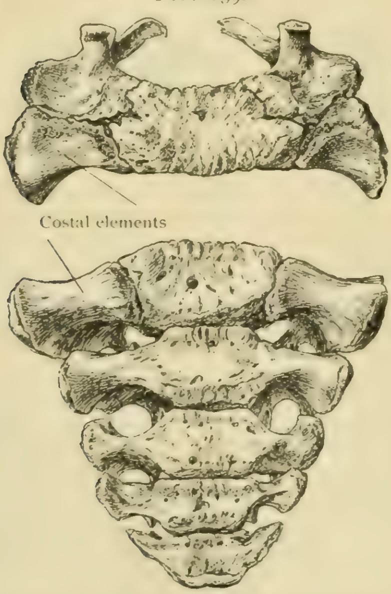
FIG. 158.



Illustrating homology of costal element (*c. e.*). *A*, sixth cervical vertebra; *B*, seventh cervical; *C*, fifth thoracic; *D*, second lumbar; *E*, fifth lumbar; *F*, sacrum in transverse section.

meet in the middle is uncertain; the arch of the first vertebra is sometimes complete at seven, those below it being still open. The five distinct sacral vertebræ which are thus formed remain separate for some time, the bodies being separated by interver-

FIG. 159.



Superior and anterior surfaces of young sacrum of about five years.

FIG. 160.

Sacrum and coccyx of about seventeen years.

tebral disks. A thin plate appears in the upper and lower parts of these disks which fuses with the bodies before the latter unite. The union of the vertebræ begins below and proceeds upward in a very irregular manner.

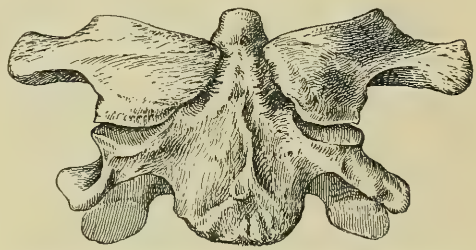
Probably union generally occurs first in the lateral masses, between the laminæ

sooner than between the bodies. By the fifteenth year the lower three vertebræ are generally fused, the second joining them from eighteen to nineteen. The five pieces are united by the twentieth year. In some cases several of the sutures are still to be seen, but all may have disappeared. The union of the bodies, as shown by sections, in the case of the upper ones, may not be complete internally till a much later period. Two thin epiphyses appear on each side of the sacrum about the eighteenth year, one for the *auricular surface* and the other below it. The lines of union of these plates may be visible after twenty-one.

The Coccyx.—Our data concerning the ossification of the coccyx are very unsatisfactory. Each segment has one centre, but the first may have two, one on each side, and, according to some, secondary centres for the cornua. Ossification begins in the first piece at about birth, and successively in the others, from above downward, until puberty. The lower three or four pieces fuse within two or three years after birth, and join the first at perhaps about twenty; there is, however, great diversity, and frequently the first unites with the sacrum instead of with the others.

The Atlas.—The atlas is almost wholly formed from two centres which appear in the seventh week of fœtal life in the root of the posterior arches; from these points ossification spreads most rapidly backward. In the course of the first year a centre is found in the middle of the anterior arch. The lateral masses meet behind in the fourth year and join the median anterior nucleus in the fifth. Sometimes the union of the posterior arches does not occur. The anterior nucleus may be absent, and the front arch may show a median suture or be represented by ligament or cartilage. In one instance the anterior arch was wholly wanting, the lateral masses being fastened to the odontoid by ligament[1] (Fig. 161).

FIG. 161.



Unique case of absence of the anterior arch of the atlas.

The Axis.—The ossification of the axis begins by two lateral points appearing by the eleventh week. The median one, which does not come till the fifth month, is at first double, but the two points speedily fuse. At about the same time two nuclei appear side by side in the odontoid process, which join together before birth, leaving a space between them at the tip. This may be closed by the extension of ossification, or a centre may appear in it at the second year, which fuses by the twelfth. The piece thus formed has been held to represent the epiphyseal plate for the top of the atlas. The odontoid process joins the body at the periphery, the union beginning in the third year and being complete a year or two later; a piece of cartilage in the middle of the juncture is said to persist under the odontoid until old age. Very rarely the odontoid remains distinct. The arches join the body in the third year, and usually meet behind at the same time; the latter union, however, may be delayed.

Variations of the Vertebræ.—The commonest and most interesting variations are those of number. These are very frequent in the coccyx, since there are originally more elements than persist, and indeed we are not sure even of the normal number in this bone. Numerical variations are also often observed in the sacral, less so in the lumbar, still less so in the thoracic, and extremely rarely in the cervical region. The number of vertebræ above the sacrum (twenty-four) is usually unchanged, but, owing to differences in development of the costal element, one region is not rarely increased or diminished at the expense of the next one. Thus the very common condition of six lumbar vertebræ is due to the want of development of the costal element (the rib) of the last thoracic, and implies only eleven vertebræ in that region. Conversely, thirteen thoracics imply an undue development of the costal element of the first lumbar, and consequently only four lumbar vertebræ. Often the costal element of the last cervical is free and over-developed, making a cervical rib. But even if this be large enough to reach the sternum, which is exceedingly rare, the number of cervical vertebræ is usually considered unchanged. Other changes are due to variations in development of the costal element in the last lumbar and the first sacral. Transitional forms are here very frequently met with. The last lumbar

[1] Dwight: Journal of Anatomy and Physiology, vol. xxi., 1887.

may, by an excessive growth of these elements, become sacralized, articulating more or less perfectly with the ilium, and, conversely, the first sacral may have almost freed itself from those below it. Thus we may find a partially sacralized vertebra, which may be either the twenty-fifth or the twenty-fourth. It often happens, particularly in the latter case, that a vertebra appears to be a first sacral on superficial examination, which is found to have little or nothing to do in forming the articular surface, in which case it is not a true sacral, for the first sacral is the *fulcralis* which has the largest surface for the joint with the ilium. A false promontory may coexist with the normal one. This is probably most frequent when the twenty-fourth vertebra is partly sacralized. Any of the preceding peculiarities may be unilateral, so that sometimes a vertebra may seem from one side to belong surely to one region, and equally surely to the other region when seen from the opposite side.

There is, however, another set of variations in which the number of presacral vertebræ is increased or diminished. There may be, for instance, one thoracic or one lumbar vertebra too many or too few, without any compensatory change in the next region. In these cases, moreover, the terminal vertebræ of the region may be very nearly typical ones, and sometimes even the size of the vertebræ will be modified so as to give the region its approximate relative length. Similar changes may be found in the neck, but they are exceedingly rare.

Variations of either kind are likely to have an effect on the column as a whole; thus, if there be a large cervical rib the last thoracic rib is likely to be small, or if the first rib is rudimentary the last is apt to be large. It follows that the thorax seems to be in certain cases moved upward or downward; this change may occur on one side only.

Rosenberg's theory, formerly much in vogue, is that there are opposite tendencies at the two ends of the spine. At the upper there is a tendency for the cervical region to encroach on the thoracic, and at the lower for each of the regions to encroach on the one above it. Such changes he considers progressive. On the other hand, the opposite movement by which the thorax encroaches on the neck or loins is considered reversive. Rosenberg has described a spine which he considers archaic, in which there are two extra presacral vertebræ and fifteen pairs of ribs, the first being cervical. There are two spines in the Warren Museum with a similar number of presacrals in which the last is sacralized on one side. As to the way in which anomalies of the lower part of the spine come about, Rosenberg[1] thinks he has shown that in the course of development the sacrum is composed of vertebræ placed farther back than the permanent ones, and that the ilium enters into connection with vertebræ more and more anterior. As new ones join it above former ones become detached from it below. If it does not make the usual progress the spine is archaic, having too many presacrals; if it goes too far the spine is of the future. Rosenberg's theory has been overthrown by Bardeen,[2] who has shown that the original position of the ilium is opposite the superior part of the lumbar region and that it travels tailwards. Having joined a vertebra at the fifth week, it never leaves it. At this early time the thoracic vertebræ are differentiated. The author[3] and Fischel[4] believe that numerical variation is the result of an error in segmentation.

A want of development of the bodies, which may be only half the normal height, is found almost exclusively in the lumbar region. We have seen (apparently congenital) fusion of the lumbar bodies while all the arches were present, but three of them crowded together. The separation of the pedicles of the fifth lumbar from the body is a very rare anomaly among whites, but not among American aborigines.

ARTICULATIONS OF THE VERTEBRAL COLUMN.

The ligaments connecting the segments of the spine may be divided, according to the parts of the vertebræ which they unite, into two groups:

1. Those connecting the Bodies of the Vertebræ;
2. Those connecting the Laminæ and the Processes.

LIGAMENTS CONNECTING THE BODIES.

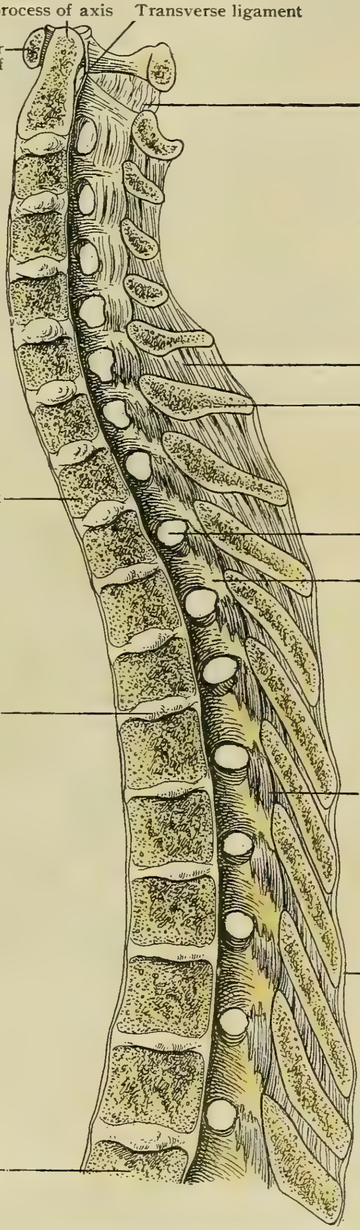
Intervertebral Disks[5] (Figs. 162, 163).—These form a series of fibro-cartilages interposed between the bodies of the vertebræ, forming about one-fourth of the movable part of the spine and adding greatly to its strength. They are developed, like the bodies, around the notochord, persisting parts of this structure forming a central core to each disk. The outer part of the disks consists of oblique layers of fibres, slanting alternately in opposite directions, some almost horizontal, which hold the vertebral bodies firmly together; the centre of the disks is occupied by a space containing fluid in the meshes of a yellowish pulp.[6] This central core is strongly compressed, so as practically to be a resistant ball within the more yielding fibro-cartilaginous socket. The proportion of the disks to the vertebral bodies varies in the different parts of the spine. They are absolutely largest in the lumbar region, but relatively in the cervical. For many reasons it is difficult to reckon the per-

[1] Morph. Jahrbuch, Bd. i. and xxvii.
[4] Anatomische Hefte, No. 95, 1906.
[2] Anat. Anzeiger, Bd. xxv., 1904, and American Journal of Anatomy, vol. iv., 1905.
[3] Dwight: Memoirs Boston Society of Nat. Hist., vol. v., 1901.

[5] Fibrocartilagines intervertebrales. [6] Nucleus pulposus.

centage very accurately, and there is much variation. The following proportions are, therefore, only approximate. The disks form in the cervical region forty per cent., in the thoracic, twenty per cent., and in the lumbar, thirty-three per cent. of the length of the spine.

FIG. 162.



Median section of upper half of spine.

Anterior and Posterior Common Ligaments.—The bodies are connected by short fibres surrounding the disks, and by long bands which are only partially separable from the general envelope. The *anterior common ligament*[1] (Figs. 163, 165) begins at the axis and extends to the sacrum. It consists of shorter and longer fibres blending with the periosteum and springing from the edges of the vertebræ and from the disks, to end at similar points on the next vertebra, or on the second, third, fourth, or fifth. The borders are not sharply defined. The *posterior common ligament*[2] (Fig. 164) is a much more distinct structure. It arises from the back of the body of the axis, receiving fibres from the occipito-axial ligament, and runs to the sacrum. It also is attached to the disks and the edges of the bodies, but possesses a distinct margin, which, except in the neck, expands laterally into a series of points at the intervertebral disks. It stands well out from the middle of the bodies, bridging over the veins of the larger ones.

LIGAMENTS CONNECTING THE LAMINÆ AND THE PROCESSES.

The **articular processes** (Fig. 165) are coated with hyaline articular cartilage and surrounded by loose *capsules*, with which, especially in the thorax, the ligamenta subflava are inseparably connected, preventing by their tension the occurrence of folds.

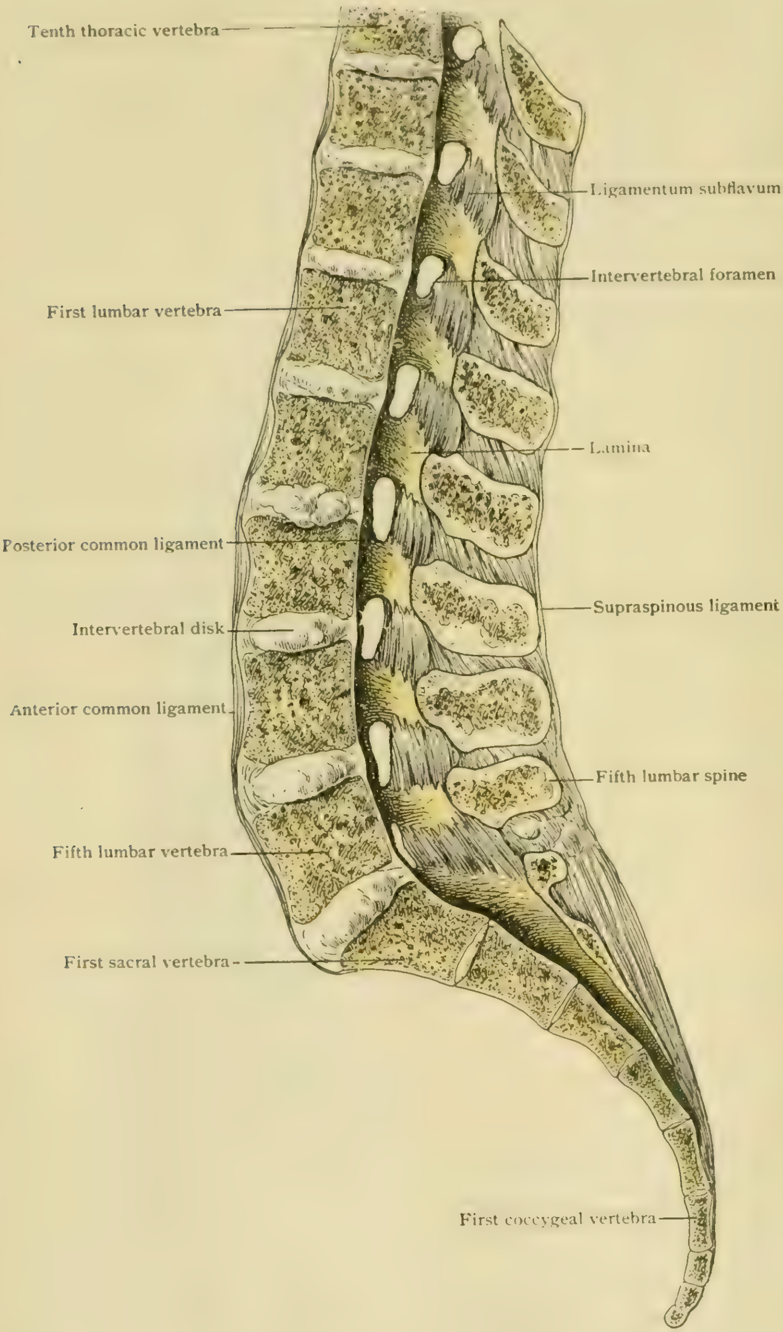
The **ligamenta subflava**[3] (Fig. 163) are elastic membranes of considerable strength connecting the laminæ from the axis to the sacrum. They are particularly developed in the lumbar region. As just mentioned, they encroach on the side of the capsules towards the canal. They also extend a short distance under the spinous processes.

The **supraspinous ligament** (Figs. 162, 163) extends as a well-marked cord

[1] Lig. longitudinale anterius. [2] Lig. longitudinale posterius. [3] Ligg. flava.

along the tips of the spines from the last cervical to the sacrum. The **interspinous ligaments** are membranes connecting the spinous processes between the tips and the laminæ, extending from the ligamenta subflava to the supraspinous ligament.

Fig. 163.

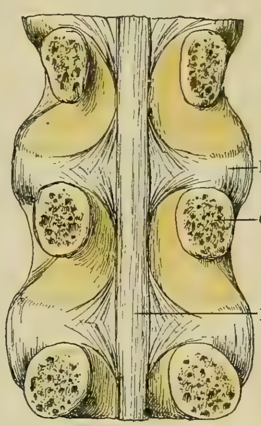


Median section of lower half of spine.

The **ligamentum nuchæ** (Fig. 166) represents in the neck a modification of the two last-mentioned ligaments. It is a vertical curtain reaching from the exter-

nal occipital protuberance to the spine of the seventh cervical, separating the muscles of the two sides. The free border is continuous with the supraspinous ligament, but, instead of touching the cervical spines, it lies in the superficial layer of muscles, and is reinforced below by radiating fibres from each of the spinous processes of the cervical region. It is inseparably blended with the origin of the trapezii and with the fasciæ between the muscular layers, especially with that covering the semispinalis and the short suboccipital muscles. In the region of the axis it is a thick median membrane; in the lower cervical region it is of little importance. In man it contains but a small proportion of elastic fibres, in marked contrast to what is found in many quadrupeds in which the structure consists principally of elastic tissue, since in these animals the ligamentum nuchæ forms an important organ for the support of the head at the end of the horizontal vertebral axis.

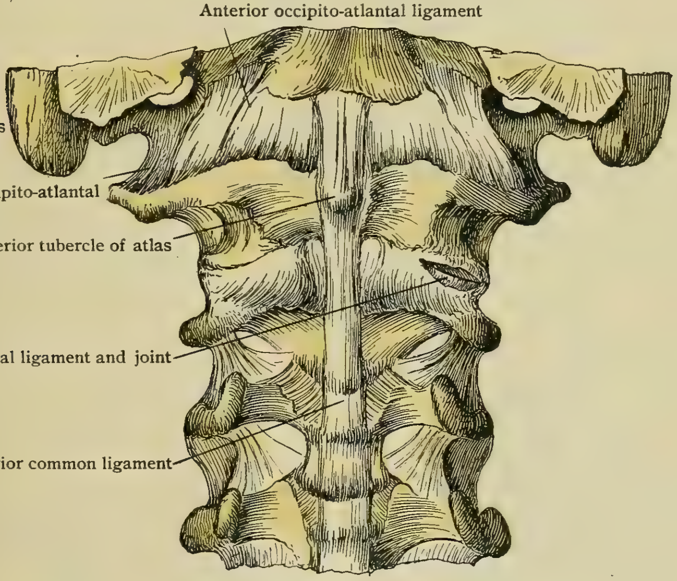
FIG. 164.



Posterior surface of bodies of vertebræ shown after removal of arches by cutting through the pedicles.

The **intertransverse ligaments** (Fig. 162) are trifling collections of fibres between the transverse processes, although occasionally distinct round cords in the thoracic region.

FIG. 165.



Anterior ligaments of upper end of spine.

ARTICULATIONS OF THE OCCIPITAL BONE, THE ATLAS, AND THE AXIS.

The arrangement here differs in some points considerably from that of the rest of the spine in order to provide for the security and the free movement of the head.

The ligaments effecting this union consist of three groups:

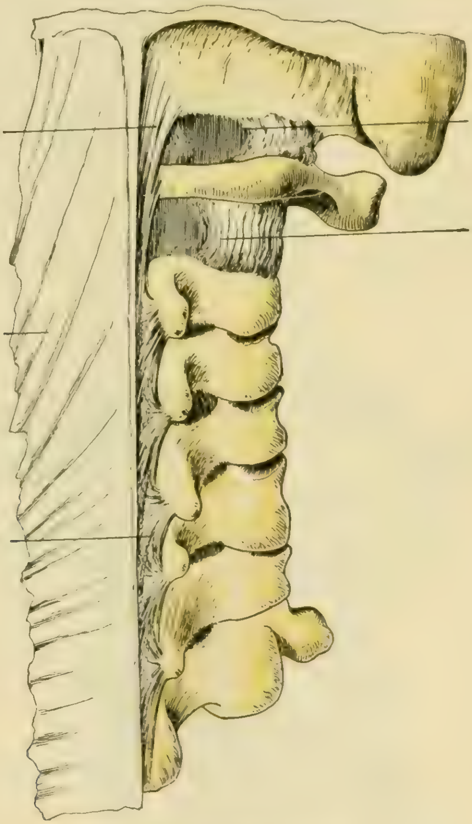
1. Those connecting the Atlas and the Axis, including the
   - Anterior Atlanto-Axial; Transverse;
   - Posterior Atlanto-Axial; Two Capsular.

2. Those connecting the Occipital Bone and the Atlas, including the
   - Anterior Occipito-Atlantal ;
   - Posterior Occipito-Atlantal ;
   - Accessory Occipito-Atlantal ;
   - Two Capsular.
3. Those connecting the Occipital Bone and the Axis, including the
   - Lateral Odontoid or Check ;
   - Middle Odontoid ;
   - Occipito-Axial.

The important peculiarities are the odontoid and the transverse ligaments.

The **odontoid,** or **check ligaments**[1] (Fig. 168), are two strong, symmetrical bundles of fibres extending from the slanting surface on each side of the top of the odontoid process outward and a little upward to a roughness on the inner side of each occipital condyle. Some fibres pass directly across from one condyle to the other. These are occasionally collected into a distinct round, glistening bundle. The space above the odontoid process, between it and the basilar process, is occupied by a mass of dense fibrous tissue reaching to the anterior occipito-atloid ligament, in the midst of which is a more or less distinct median band connecting these parts, the **middle odontoid ligament.**[2] A *supra-odontoid bursa* may be developed in this tissue.[3]

FIG. 166.



Ligaments of back of neck.

The **transverse ligament**[4] (Figs. 167, 168) of the atlas is a strong band passing between the tubercles on the inner side of each lateral mass of the atlas. It does not run straight, but curves backward around the odontoid, from which it is separated by a bursa. A band from the middle of the transverse ligament passes upward to the cerebral side of the basilar process, and another downward to the body of the axis, so that the whole structure is called the **cruciform ligament.**[5]

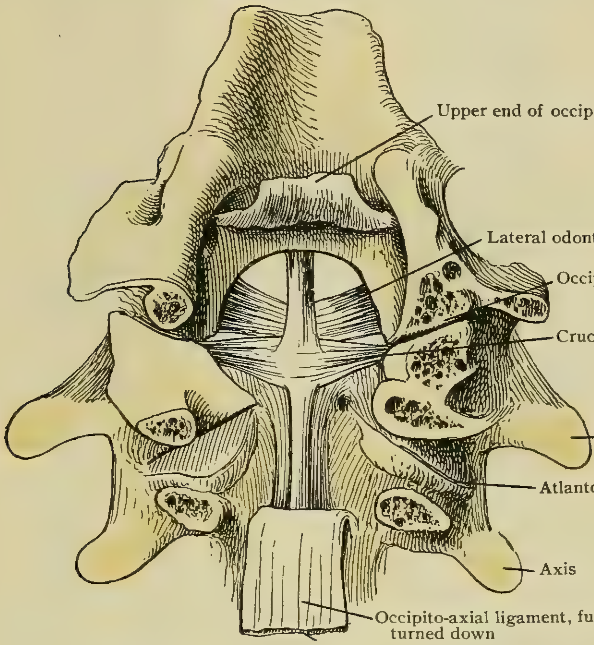
[3] Trolard : Journ. de l'Anat. et de la Physiol., 1897.

[1] Ligg. alaria. [2] Lig. apicis dentis. [4] Lig. transversum atlantis. [5] Lig. cruciatum atlantis.

Another bursa lies between the odontoid and the anterior arch of the atlas. The transverse ligament and the two check ligaments are in series with the interarticular ligaments of the heads of the ribs.

The other ligaments of this region are in the main simple membranes connect-

FIG. 167.



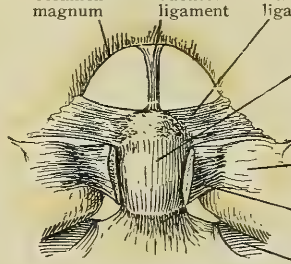
Back of occiput and arches removed; occipito-axial ligament cut and turned down.

ing neighboring parts. The **anterior occipito-atlantal ligament**[1] (Fig. 165) extends between the front of the foramen magnum and the anterior arch of the atlas; the **anterior atlanto-axial** (Fig. 165) is in serial continuation with it. A distinct rounded, raised band, the **accessory occipito-atlantal**, passes in the median line from the under side of the occiput to the front tubercle of the atlas (Fig. 165), and thence to the body of the axis, where it joins the anterior common ligament of the spine.

The **occipito-axial ligament**[2] (*apparatus ligamentosus*) (Fig. 167) descends inside the spinal canal from the basilar process to the body of the axis, where it joins the posterior common ligament and completely conceals the odontoid process and its special ligaments.

The **posterior occipito-atlantal**[3] and the **posterior atlanto-axial ligaments**[4] lie in the region of the arches (Fig. 166). The former extends between the posterior border of the foramen magnum and the arch of the atlas; the latter between the arch of the atlas and that of the axis. These are in series with the ligamenta subflava, but differ from them in being non-elastic. In the former of these membranes there is an opening just behind the facets on the atlas for the condyles, bridged over by a band, for the entrance of the vertebral artery.

FIG. 168.

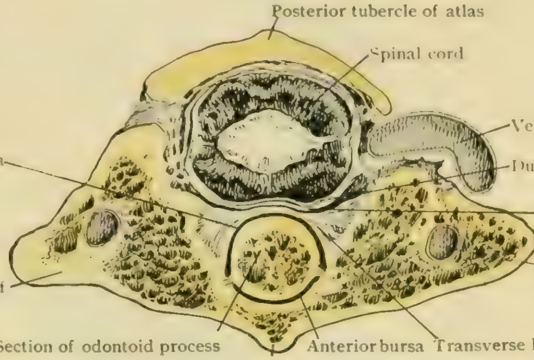


Posterior surface of odontoid process shown by removal of middle of transverse ligament; basilar process is thrown strongly upward.

[1] Membrana atlantooccipitalis anterior. [2] Membrana tectoria. [3] Membrana atlantooccipitalis posterior. [4] Membrana atlantoepistrophica.

Synovial joints, the shapes of which are described with the bones, exist between the *occipital bone* and the *atlas* and between the *atlas* and the *axis*. The capsule of the upper joint is very thick, especially behind, where it is continuous with the posterior occipito-atloid ligament. The capsule surrounding the articular surfaces of the atlas and axis is strengthened posteriorly by a bundle running upward and outward from the axis.

FIG. 169.



Transverse section of spine passing through atlas and odontoid process.

THE SPINE AS A WHOLE.

Anterior Aspect (Fig. 170).—The bodies enlarge, in the main, regularly from above downward. This progression is interrupted only by a slight decrease from the first to the fourth thoracic. In the cervical region the origin of the costal elements from the sides of the bodies gives the latter a false appearance of breadth. The middle of the thoracic region is particularly prominent in front, owing in part to the aortic depression on the left. A slight curve to the right in this region is generally seen; it is probably attributable to this cause.

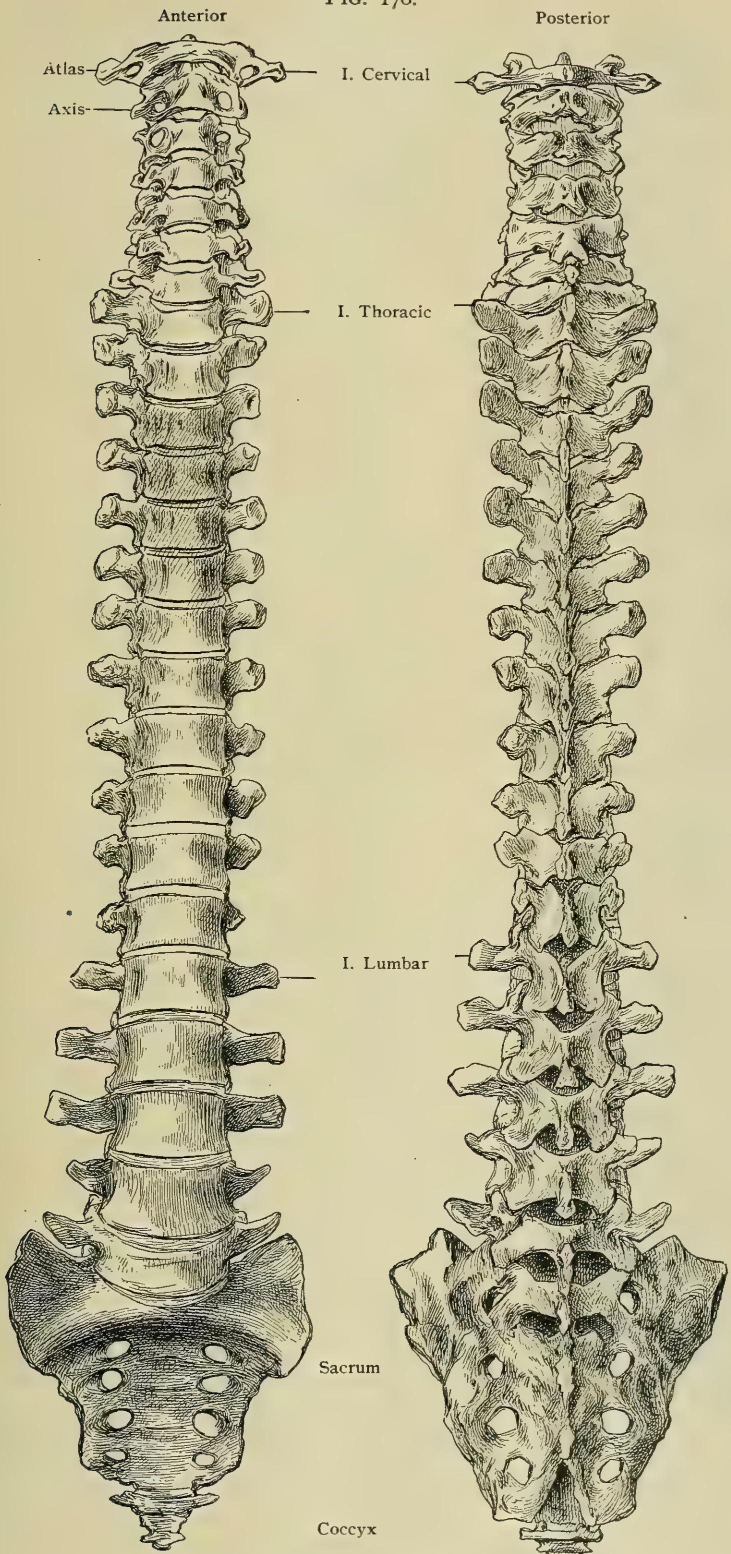
Posterior Aspect (Fig. 170).—A deep gutter extends on each side of the spinous processes, bounded externally in the neck and loins by the articular processes and in the back by the transverse. In the latter region the spines which are subcutaneous are often deflected from the median line, and may be arranged in zigzag. The laminæ completely close the spinal canal in the convex thoracic and sacral regions, while it is left open in the neck and loins, except during extension of the former.

Lateral Aspect (Fig. 171).—The profile view shows best of all the increase in the importance of the bodies from above downward, and coincidently with this the gradual moving backward of the intervertebral foramina. These increase greatly in size from the lower part of the thoracic region.

The Curves.—The curve of the spine is necessarily an arbitrary one, since it varies not only in individuals and according to age, sex, and occupation, but also with position and the time of day, being longer when lying than standing, and after a night's rest than after a day's work. The difference occasioned by position occurs especially in youth, when it may amount to half an inch or more. It is of little consequence after middle age. Bearing these variations in mind, the following guide to the curve, suggested by Humphry, may be accepted: a line dropped from the middle of the odontoid process passes through the middle of the body of the second thoracic, that of the twelfth thoracic, and the anterior inferior angle of the fifth lumbar. Henle divides the spine into four quarters; and although this method has the defect of using the unreliable pelvic section, it very often proves remarkably correct. Thus, if we continue Humphry's line to the level of the tip of the coccyx, the middle point is opposite the eleventh thoracic, the end of the first quarter opposite the lower border of the third thoracic, and that of the third quarter opposite the lower edge of the fourth lumbar.

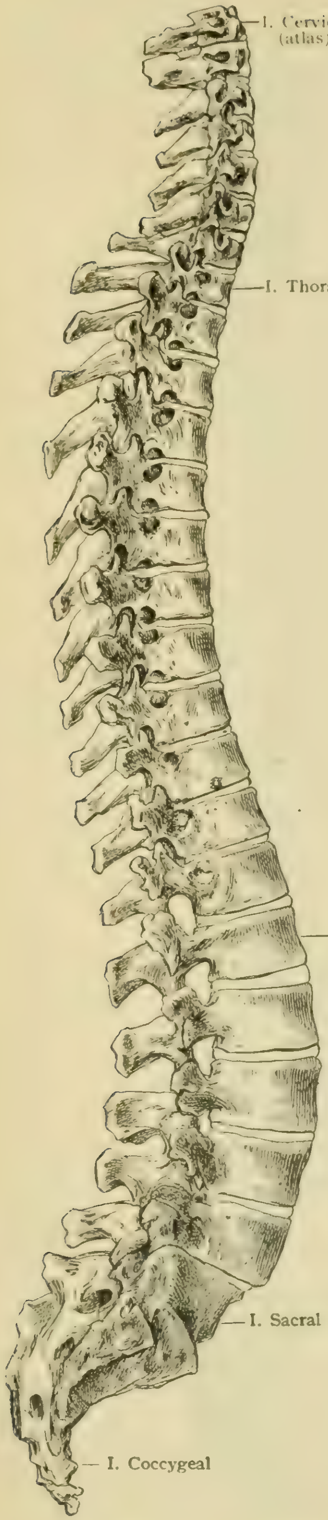
The development of the curves can hardly be said to have begun at birth. At

FIG. 170.



Anterior and posterior views of adult spine.

FIG. 171.



Lateral view of adult spine.

that age the infant's spine presents in front one general concavity, slightly interrupted by the promontory of the sacrum. The ligamentous spine, containing little bone, is exceedingly flexible in any direction : the atlas can be made to touch the sacrum. It is more accurate to say that the general axis of the spine is a curved one than that any permanent or fixed curve exists. The cervical curve appears as the infant grows strong enough to hold up its head ; it is never, properly speaking, consolidated (Symington), since it is always obliterated by a change in the position of the head. The lumbar curve appears at from one to two years when the child begins to walk. The mechanism of its production is explained as follows. When an infant lies on its back the thighs are flexed and fall apart. If these be held together and pressed forcibly down, the lumbar region will spring upward, owing to the shortness of the ilio-femoral ligaments, which bend the pelvis and, indirectly, the spine. The psoas muscles, moreover, act directly on the spine. When the child first stands, the body is inclined forward ; when the muscles of the back straighten it, the lumbar curve is produced by the same mechanism, since it is immaterial whether the legs are extended on the trunk or the trunk on the legs. How or when these curves become consolidated is very difficult to determine. The influence of differences in thickness of the front and back of the various bodies and disks is inappreciable in the neck ; in the lower part of the back and in the first, and perhaps the second, lumbar vertebræ the height is greater behind. In the loins the fifth vertebra is much thicker in front and, above it, the fourth and third in a less degree. The intervertebral disks are also much thicker in front. How soon actual difference in the diameters of the vertebræ appears is uncertain. A child of about three shows little of it, except in the last lumbar, and, according to Symington's plates, there is not much more difference at five or even thirteen years. It is certain that throughout the period of growth the curves can be nearly or quite effaced. The restraining influences are the gradually developing differences in the vertebræ and the disks, the effect of the sternum and the ribs on the thoracic region, the pull of the elastic ligaments of the arches, and perhaps, above all, muscular tonicity. In the latter part of middle age the curves of the back and loins become consolidated ; this is, however, distinctly a degenerative process.

Dimensions and Proportions.—The length and the proportions of the different presacral regions (including the intervertebral disks), measured along the anterior surface of the spine, have, in fifty males and twenty-three female bodies, been found by us as stated below. We give for comparison Ravenel's[1] and Aeby's[2] proportions combined. The former measured eleven and the latter eight spines of each sex. Cunningham's[3] proportions, from six male and five female spines, are also added. In the proportions, one hundred represents the total presacral length along the curves.

ACTUAL LENGTH OF PRESACRAL REGIONS OF SPINE.

	Male. Centimetres.	(Inches.)	Female. Centimetres.	(Inches.)
Neck	13.3	(5.25)	12.1	(4.75)
Back	28.7	(11.31)	26.5	(10.44)
Loins	19.9	(7.82)	18.7	(7.38)
	61.9	(24.38)	57.3	(22.57)

PROPORTIONS OF PRESACRAL REGIONS OF SPINE.

	Male. (Dwight.)	(R. & A.)	(Cunningham.)	Female. (Dwight.)	(R. & A.)	(Cunningham.)
Neck	21.5	21.7	21.8	21.2	21.7	21.6
Back	46.3	46.7	46.5	46.1	46.5	45.8
Loins	32.2	31.4	31.7	32.7	32.4	32.8
	100.0	99.8	100.0	100.0	100.6	100.2

Thus, while it is true that the lumbar region is relatively longer in woman, the difference is trifling.

ABSOLUTE AND RELATIVE LENGTH OF PRESACRAL REGIONS DURING GROWTH.

Age.	Observer.	Absolute Length. (In Millimetres.) Neck.	Back.	Loins.	Total.	Relative Length. (Total = 100.) Neck.	Back.	Loins.
At birth	Ravenel.	50	93	50	193	25.9	48.2	25.9
At birth	Ravenel.	40	100	50	190	21	52.6	26.3
At birth	Ravenel.	40	95	50	185	21.6	51.3	27
One month	Chipault.[4]	40	80	45	165	24.2	48.4	27.4
One month	Chipault.	42	80	44	166	25.3	48.1	26.6
Three months	Ravenel.	50	100	58	208	24	48.1	27.9
Six months	Aeby.	52.5	103	60	215.5	24.3	47.5	27.8
Six months	Aeby.	53.5	107	61	221.5	24.1	48.6	27.5
Ten months	Dwight.	61	125	77	263	23.2	47.5	29.2
One year, boy	Chipault.	60	121	72	253	23.7	47.8	28.5
One year, boy	Chipault.	69	129	83	281	24.5	45.9	29.6
One year and one month, boy	Chipault.	67	118	79	264	25.2	44.8	30
One and a half years, girl	Chipault.	62	130	69	261	23.7	49.7	26.6
One and a half years, boy	Chipault.	68	132	79	279	24.3	47.4	28.3
Two years, boy	Ravenel.	70	140	90	300	23.3	46.7	30
Two years, boy	Aeby.	79.5	153.5	98	331	24	46.4	29.6
Three years, girl	Dwight.	78	162	101	341	22.9	47.5	29.6
Four years, girl	Aeby.	79.9	162	103.3	345.2	23.1	46.9	29.9
Four and a half years, boy	Chipault.	81	174	102.8	357.8	22.6	48.9	28.5
Five years, boy	Symington.[5]	80	170	104	354	22.5	48	29.4
Five years, boy	Ravenel.	80	180	135	395	20.3	45.6	34.2
Six years, boy	Symington.	80	175	106	361	22.2	48.5	29.3
Nine years, girl	Ravenel.	85	195	150	430	19.8	45.4	34.9
Eleven years, boy	Aeby.	91	218.7	153.5	463.2	19.7	47.2	33.1
Thirteen years, girl	Symington.	95	220	136	451	21.5	48.7	29.1
Fifteen years, boy	Dwight.	120	265	183	568	21.1	46.6	32.2
Sixteen years, girl	Aeby.	100	221.8	151	472.8	21.1	46.9	31.9
Sixteen years, girl	Aeby.	107.5	229.5	152.5	489.5	21.9	46.9	31.1
Seventeen years, girl	Dwight.	113	250	161	524	21.5	47.7	30.7

[1] Zeitschrift für Anat. und Entwicklng., 1876.
[2] Arch. für Anat. und Entwicklng., 1879.
[3] Cunningham: Memoirs, 1886.
[4] Revue d'Orthopédie, 1895.
[5] The Anatomy of the Child.

It appears from the above that in the adult the neck is a little more than one-fifth of the movable part of the spine and the loins a little less than one-third. In the young embryo these proportions are reversed, but by the time of birth these two parts are nearly equal.

Movements of the Head.—Those between the *occiput* and *atlas* are almost wholly limited to *flexion* and *extension*, of which the latter is much the greater. This is in part due to the reception of the posterior pointed extremities of the articular processes of the atlas into the inner parts of the posterior condyloid fossæ. The anterior occipito-atlantal ligament and the odontoid ligaments are tense in extreme extension. In *flexion* the tip of the odontoid is very close to, if it does not touch, the basilar process. The range of both these motions is much increased by the participation of the cervical region. There may be a little *lateral motion* between the atlas and head, and there is some slight *rotation*. The great variation of the shape of the articular facets makes it clear that both the nature and extent of the motions must vary considerably.

The joint between the *atlas* and *axis* is devoted almost wholly to *rotation*. The transverse ligament keeps the odontoid in place, and the very strong odontoid ligaments check rotation alternately. The head is highest when directed straight forward, but the joints are in more perfect adaptation if one condyle be a little anterior to the other, and if the atlas be slightly rotated on the axis. This position, though entailing a slight loss of height, is the one naturally chosen as that of greatest stability.

Movements of the Spine.—The very extensive range of motion of the whole spine is the sum of many small movements occurring at the intervertebral disks. The whole column is a flexible rod, but this conception is modified by the following peculiarities : (1) the motion is not equally distributed, owing to the varying distances between the disks and the differences of thickness of the disks themselves ; (2) the bodies, which form the essential part of the rod, are not circular, so that motion is easier in one direction than in another ; (3) the rod is not straight but curved ; (4) the kind of motion is influenced by the articular processes, and varies in the different regions. Other modifying circumstances exist, but these suffice to show that, while certain general principles may be laid down, an accurate analysis of the spinal movements is absolutely impossible.

The incompressible semifluid centre of each disk has been compared to a ball on which the rest of the disk plays. This would, therefore, be a universal joint were there no restraining apparatus. The motions are *flexion* and *extension*,—*i.e.*, angular movements on a transverse axis ; *lateral motion*,—*i.e.*, the same on an antero-posterior axis, and *rotation* on a vertical axis. It is unlikely that any single one of these motions ever occurs without some mingling of another. Flexion and extension are greatest in the neck and loins. Extension is more free than flexion in the neck, where it is limited by the locking of the laminæ, which, when the head is thrown as far back as possible, gives great rigidity to the neck. In the loins and in the region of the last two thoracic vertebræ flexion is the more extensive. Before the spine is consolidated, slight flexion is possible throughout the back, but extension is very quickly checked by the locking of the laminæ and spines. Lateral motion is greatest in the neck, considerable in the back and least in the loins. Such motion is always associated with rotation, which is most free in the neck, considerable in the back, and very slight, at most, in the loins. It is to be remembered that motions both in the antero-posterior and in the transverse plane are checked by the tension of the ligaments on the side of the body of the vertebra opposite to the direction of the motion, and also by the resistance to compression of that side of the intervertebral disk towards which the motion occurs. The ligamenta subflava, being elastic, tend continually to bring the bones back into position from the innumerable slight displacements to which they are subject. That this replacement is effected by a purely physical property of the tissue instead of by muscular action implies a great saving of energy. The amount of all motions, and of rotation in particular, decreases throughout life and varies much in individuals. According to Keen, the rotary motion between the atlas and the axis amounts to twenty-five degrees, that in the rest of the neck to forty-five degrees, and that of the thoracic and lumbar regions to about thirty degrees on each side.

PRACTICAL CONSIDERATIONS.

While the number of vertebræ in the neck is almost invariable in man (and indeed in all the mammalia except the sloth and the sea-cow), the length of the cervical region varies greatly in individuals. As it is apparently shortened during full inspiration and lengthened during full expiration, so an actual change in its length is associated with the types of thorax that correspond to these conditions. The long neck is therefore found in persons with chests that are flat above the mammæ, with wide upper intercostal spaces and narrow lower ones, and with lack of prominence of the sternum. These conditions are often associated with phthisical tendencies. The short neck is found in persons with chests of the reverse type. Its theoretical association with apoplectic tendencies is very doubtful.

The remaining variations both in the length and in the shape of the vertebral column are closely connected with corresponding variations in its curves.

The normal curves of the spine are four: the cervical, thoracic, lumbar, and pelvic (or sacro-coccygeal). The cervical and lumbar are concave backward, the thoracic and pelvic convex backward (Fig. 171). These curves are produced and kept up partly by the twenty-three intervertebral disks. They are altered by disease. An additional curve not uncommon in absolutely healthy persons consists in a slight deflection of the thoracic spine to the right; this asymmetry is usually ascribed to the greater use of the right arm, but it is due to the position of the heart and the aorta.

All the vertebral bodies are composed of cancellous tissue, which is more spongy in direct proportion to the size of the vertebræ, and therefore is least so in the neck and most spongy in the lumbar region. This corresponds with the greater succulence and elasticity of the lower intervertebral disks and aids in minimizing the effect of jars and shocks such as are received in alighting from a height upon the feet, the lower portion of the column of course receiving the greater weight. If in such falls the calcaneum or tibia is broken, the spine usually escapes injury. If the lower extremity remains intact, the safety of the spine depends largely upon the elasticity given by its curves and by the disks.

The fact that the bodies have to bear the chief strain of such shocks and of extreme flexion and extension, the most usual forms of spinal injury, serves, together with their comparative vascularity, to make them the seat of tuberculous infection when it invades the spine. Their spongy texture, once they are softened by inflammation, leads to their ready disintegration under the superincumbent weight. In the neck and in the loins the process may at first merely cause a straightening of the column, the normal curves being concave backward. In the thoracic region—the most common situation—it soon produces *kyphosis*, an exaggerated backward curve, the sharp projection of the spinous processes of the affected vertebræ causing it to be known as "angular curvature." The abscesses which result from caries of the vertebræ are governed as to their position and course by the fasciæ and muscles that surround them. They will, therefore, be described later (page 643).

The suspension of the whole body from the chin and occiput separates the individual vertebræ so that they are held together mainly by their ligaments. This obviously relieves or removes the pressure of the superincumbent weight on the bodies of diseased vertebræ. The relief of pressure in cases of thoracic caries is continued by the use of appliances which transfer the weight of the head and shoulders to the pelvis. The simplest of these is the plaster jacket. For cervical caries, the weight of the head is transferred to the trunk beneath the level of disease by means of an apparatus extending from above the head to a band (of leather or plaster) encircling the chest.

In cases of kyphosis corrected by the method of "forcible straightening" it is obvious that a gap proportionate to the amount of bone which has previously been destroyed must be left between the bodies of the diseased vertebræ. The ultimate integrity of the spinal column will depend upon the extent and character of the ankylosis which takes place between the separated vertebræ. It is asserted (Calot) that such consolidation does occur between the bodies in moderately severe cases, and between the laminæ, transverse processes, and spines in the more serious

ones. It has been shown (Wullstein) that injury to the dura and cord and even fracture of the arches and processes are possible concomitants of forcible rectification of kyphosis.

If the curve forward of the lumbar spine is exaggerated, constituting *lordosis*, it is usually compensatory, and is acquired in an effort to maintain the erect position, as in cases of high caries, great obesity, pregnancy, ascites, abdominal tumors, etc.

Scoliosis or *lateral curvature* commonly results from faulty positions in young, undeveloped persons with weak muscles, as school-girls, who sit or stand in such attitudes that the muscles are relieved and the strain is borne by insensitive structures, like ligaments and fasciæ. This results in a deflection of one part of the column—generally the thoracic—to one side, usually the right, and the formation of a compensatory curve below, and occasionally of one above also. The bodies of the affected vertebræ are at the same time rotated, partly by the action of the slips of the longissimus dorsi which are attached to the ribs near the angles and to the tips of the transverse processes (Fig. 520), so that in advanced cases the tips of the spinous processes of the affected segments turn towards the concavity of the curves, while the transverse processes of the vertebræ involved tend to lie in an antero-posterior plane and can often be felt projecting backward.

A further explanation of the causes of the rotation may be found in the behavior of a straight flexible rod under similar conditions. Torsion results from any motion in which all particles of a straight flexible rod do not move in parallel columns. Therefore, if it be bent in two planes at the same time torsion must inevitably occur. The vertebral column being bent in the antero-posterior plane by a series of gentle curves, lateral bending must, therefore, inevitably lead to torsion, since it means bending in two planes.

A little consideration of the relations of the spine to the ribs, scapula, and pelvis will show that lateral flexion and rotation cannot take place without causing (*a*) separation of the ribs on the convex side; (*b*) change in the costal angles, making the ribs more horizontal on the convex and more oblique on the opposite side; (*c*) undue prominence of their angles on the convex side, the scapula being carried upon them so that it also is more prominent; (*d*) diminution of the ilio-costal space on the concave side; (*e*) elevation of the shoulder on the convex side; (*f*) flattening of the chest in front on the convex and undue prominence of the chest on the opposite side; (*g*) projection of the ilium on the concave side. Lateral curvature with these secondary deformities may also be produced by unequal length of the lower limbs, one-sided muscular atrophy, hypertrophy, or spasm, sacro-iliac disease, empyema, and asymmetry of either the pelvis or the head.

The latter factor is especially interesting from an anatomical stand-point. From what has been said (page 142) of the position of greatest stability of the joints between the head and the atlas and the latter and the axis, it is evident that the position of greatest ease is with the head slightly turned to one side, the condyles of the occiput not being in their best contact with the superior articular surfaces of the atlas when the head is held straight, but rather when the head is slightly twisted (Dwight). The effects of this are far-reaching. First, there is an instinctive effort to get the eyes on the same plane in looking forward, which is presumably the primary cause of the asymmetry of the face that is usually found. It is also easier to support the weight in standing chiefly on one leg, hence the other side of the pelvis is allowed to fall so that the lumbar region slants away from the supporting leg. This must be corrected by a lateral motion of the spine above it, and as this is not pure but mixed with rotation, there occurs a twist in the spine; one shoulder is higher than the other as well as farther forward. In healthy persons such positions, if not maintained too long, do little harm; but there is likely to be some spinal asymmetry in all, and there is the danger that it may become pronounced and fixed in the weak.

Sprains of the spine are most common in the cervical and lumbar regions: in the former because of the greater mobility of the articulation with the cranium, and in both because of their own mobility, the greatest degree of bending in an antero-posterior direction being possible in those two segments of the spine. The thoracic and pelvic curves are primary, form part of the walls of the thorax and pelvis,

appear early, and are chiefly due to the shape of the vertebral bodies. The cervical and lumbar curves are secondary, develop after birth, and depend mainly on the shape of the disks. Greater mobility would naturally be expected under the latter circumstances. The close articulation between the separate vertebræ throughout the whole column, while it renders a slight degree of sprain not uncommon, tends at the same time to diffuse forces applied to the spine and to concentrate them within certain areas. These areas are the points at which fixed and movable portions of the spine join each other, as in the neighborhood of the atlanto-axial, the cervico-thoracic, and the thoracico-lumbar regions.

If the force is sufficient to cause an injury of greater severity than a sprain it is apt to be a dislocation or a fracture with dislocation at one or other of these localities. The latter accident is usually caused by extreme flexion of the spine, and of the three points mentioned is most often found in the segment including the lower two thoracic and the upper one or two lumbar vertebræ. This is due to the fact that (1) this segment has to bear almost as much weight as the lumbar spine, and yet its vertebræ are smaller and weaker. (2) The transverse processes are short, while the longer ones below, together with the crest of the ilium and the ribs above, give a powerful leverage to the muscles that move the region in question. (3) It is the region at which the most concave part of the thoracico-lumbar curve is found, making the "hollow of the back" and corresponding to the "waist" where the circumference of the trunk is smallest. (4) Its nearness to the middle of the column enables a greater length of leverage to be brought to bear against it than against any other part. (5) The different segments of the spine above it are comparatively fixed (Humphry). These anatomical facts account for the frequency and severity of the injury known as "fracture-dislocation" in this region as a result of extreme flexion.

A view of the vertebral column from behind (Fig. 170) serves well to illustrate some of these points.

Pure dislocations are rare, but are more frequent in the upper than in the lower part of the spine, because the bodies of the cervical vertebræ are small, and the interlocking of the articular processes is less firm than it is lower in the column. The vertebra most commonly dislocated is the fifth cervical, which might be expected from the fact that in the neck flexion and extension are freest between the third and sixth vertebræ. The dislocation is usually anterior,—that is, the articular process of one vertebra slips forward and falls down on the pedicle of the vertebra below, resting in the intervertebral notch,—this accident being rendered easy by the comparatively horizontal position of the articular processes in the cervical region. Such dislocation is practically impossible in the thoracic or lumbar region without fracture, while fracture is comparatively rare in the cervical region. The lumen of the spinal canal may be but little, if at all, invaded.

As to reduction, experiments show (Walton) that no moderate amount of extension in a direct line would raise the displaced articular processes in the least degree. It was, however, found easy to unlock these processes by retro-lateral flexion, bending the head towards the side to which the face was already turned, an inappreciable amount of force being necessary. Rotation into place completed the reduction.

All pure dislocations are really subluxations, as without extensive fracture of the processes and great laceration of ligaments a complete separation of the articular surfaces of two adjoining vertebræ is practically impossible.

Pure fracture, not the result of a gunshot wound, is rare. If from flexion, the fracture involves the body; if from direct violence, usually the laminæ. These facts require no explanation.

Dislocations and fractures of the upper two cervical vertebræ are especially serious on account of the proximity of the medulla and of their position above the roots of the phrenic nerve and of the nerves supplying the external muscles of respiration. If the accident is from overflexion, it may be a dislocation between the occiput and the atlas, as it is there that the movements of flexion and extension of the head take place. If it arises from extreme rotation, and especially if there is rupture of the check ligaments, it may be a dislocation of the atlas from the axis, as it is there that the rotary movements of the head occur. "A dumb person expresses 'yes' at the

occipito-atloid joint and 'no' at the atlo-axoid'' (Owen). Painless nodding and rotation of the head aid, therefore, in the exclusion of the occipito-atlantal and atlanto-axial regions in obscure cases of high caries.

The axis is more spongy than the atlas, and is weakest about one centimetre below the neck of the odontoid process, and this is one of the most frequent seats of fracture.

In fracture-dislocations, which constitute from seventy to eighty per cent. of severe spinal injuries, the thoracico-lumbar region suffers most commonly for the reasons above stated. The almost vertical direction of the articular processes of the thoracic vertebræ causes them, when flexion is extreme, as when a weight has fallen on the back, to be frequently fractured, which, together with the accompanying crushing of the vertebral body and rupture of the supra- and interspinous ligaments and the ligamenta subflava, permits the immediate sliding forward of the vertebræ above the crushed one and the compression of the cord—often its practical severance—between the anterior edge of the posterior arch of the upper vertebra and the posterior edge of the body of the lower one.

(For the resulting symptoms, see section on Nervous System, page 1053.) It may be mentioned here that the spinal nerves do not arise from the cord opposite the vertebræ after which they are named. Their regions of origin may briefly be stated as follows :

(1) Occiput to sixth cervical spine,—eight cervical nerves.
(2) Seventh cervical to fourth thoracic spine,—upper six thoracic nerves.
(3) Fifth to tenth thoracic spine,—lower six thoracic nerves.
(4) Eleventh and twelfth thoracic spines,—five lumbar nerves.
(5) First lumbar spine,—five sacral nerves.

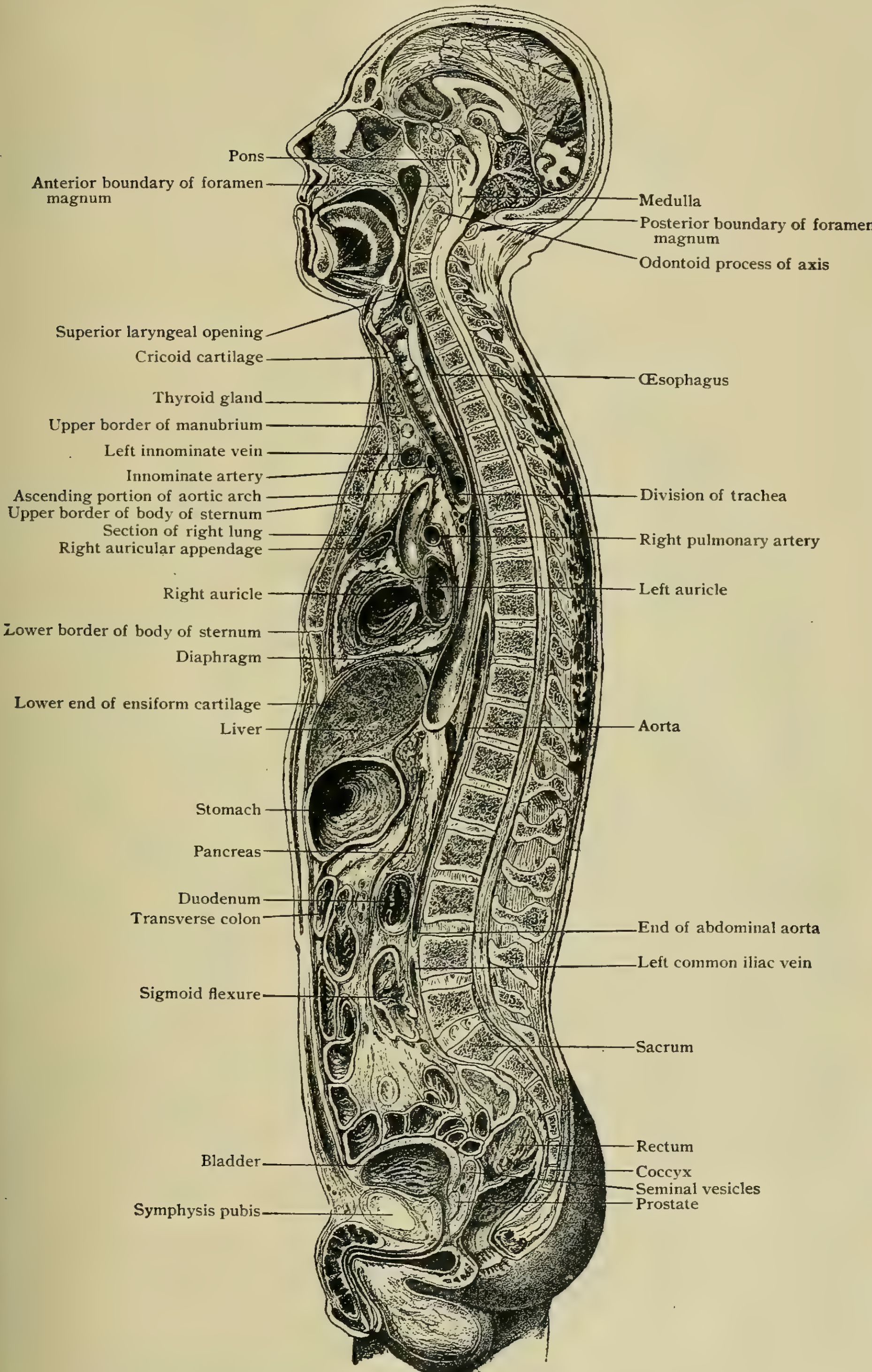
Landmarks.—To fix the limits of the spine in the living, draw a horizontal line from the anterior nasal spine to the lower edge of the external occipital protuberance and another backward from the top of the symphysis pubis. Seen from the side, the top of the spine is in a line connecting the front of the lobe of each ear, passing behind the neck of the lower jaw. Frozen sections show that the front of the vertebral bodies is much nearer the centre of the body than one is prepared to expect. A vertical transverse, or frontal, plane through the thorax at its greatest breadth strikes the angle of the jaw, the front of the cervical convexity of the spine, and cuts the body of the fourth lumbar (Langer).

The relations of the spine anteriorly are considered with the parts in front of it. The parts felt from the surface are the spinous processes and some few of the transverse ones. The line of the spines is a good example of the general rule that prominences on the skeleton lie in hollows in the flesh ; a deep furrow between the muscular masses marks their position.

Palpation of the normal spine with the soft parts in place gives the following information. The spine of the second cervical can be felt by deep pressure a little below the occiput. The short spines of the succeeding vertebræ are made out with great difficulty. The fifth is longer than those just above it. The sixth is much longer and nearly as long as that of the seventh. The name *vertebra prominens* conferred on the seventh is misleading, for the spine of the first thoracic is the most prominent in this region. The third, fourth, and fifth cervical spines recede from the surface by reason of the forward curve of the cervical segment and on account of their shortness. This permits of free extension of the head and neck. The ligamentum nuchæ also prevents them from being felt distinctly. The sixth and seventh cervical and first thoracic are easily felt. The remainder, lying in the groove caused by the prominence of the erector spinæ muscles, can usually be palpated without much difficulty.

The relative sizes vary so much that it is not safe to identify any spine in this way. If the whole series from the second cannot be counted, it is best to start from the fourth lumbar, which is on a level with the highest points of the ilia. Vertebræ can also be identified from the lower ribs by the relations of the heads to the bodies. The relations of the spinous processes to the body vary. Thus, in the cervical region the first five spines pass nearly straight backward. The sixth and seventh, like the upper two or three thoracic spines, descend a little, so that the tip is opposite

FIG. 172.



Median section of the body of a man aged twenty-one years. (*After Braune.*)

to the body next below it. With the fourth or fifth thoracic they point much more strongly downward, so as to be opposite the disk below the succeeding body. This continues to the tenth, where they are opposite the body below. In the loins the spines have a considerable posterior surface, which is opposite the disk and the upper part of the body below it. The tips of the spines are not always in a straight line, but sometimes describe a zigzag. The transverse process of the atlas can be felt below the tip of the mastoid process, moving with the head when the latter is turned. The transverse processes below this are felt with great difficulty through the muscles of the side of the neck. Those of the back and loins are too thickly covered to be felt. The laminæ are also thickly covered with muscles, so that the operation of laminectomy necessarily involves a deep wound, and in the thoracic region this difficulty is increased by the backward projection of the ribs.

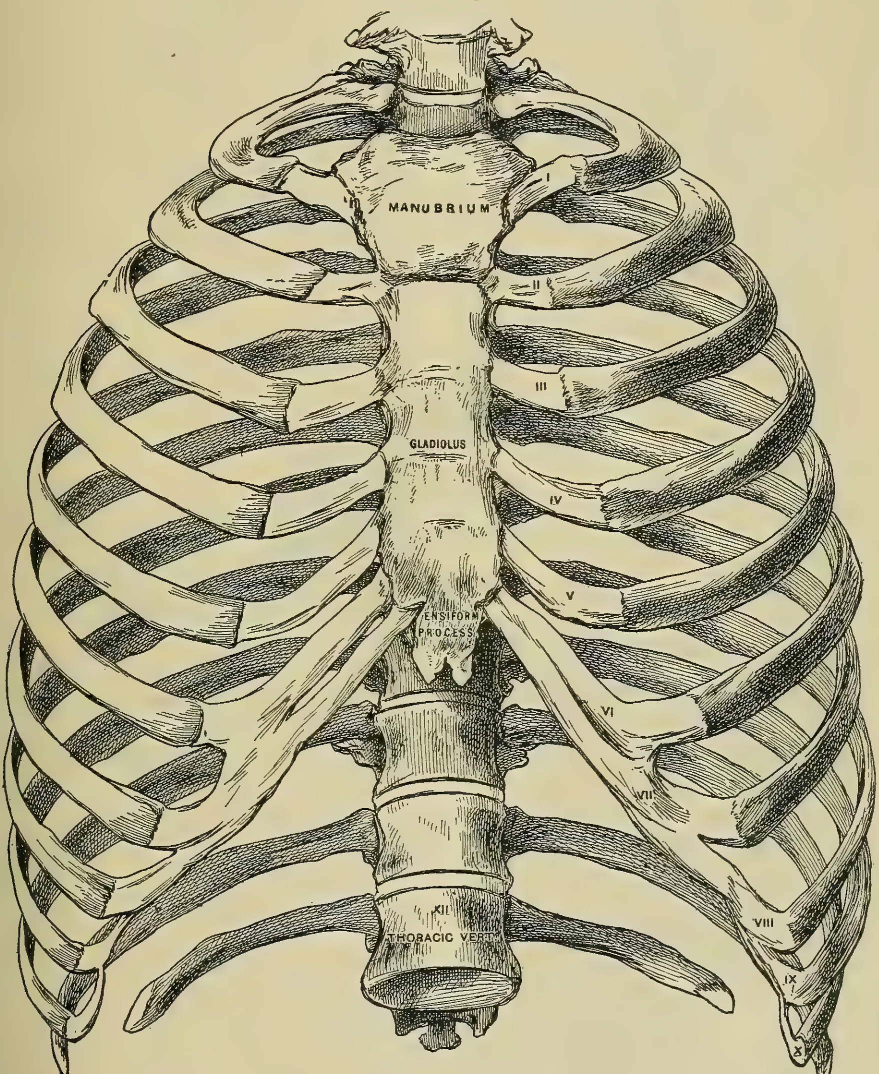
As landmarks the *spines* of the vertebræ, on account of their accessibility, have great value. These spines have the following relations. The *fourth cervical* spine corresponds to (1) the opening of the larynx; (2) the bifurcation of the carotid artery, and hence the point of origin of both the external and internal carotid arteries. The *sixth cervical* indicates the level of the carotid tubercle (transverse process of the sixth vertebra) and the entrance of the vertebral artery into the bony canal. The *seventh cervical* spine is a guide to (1) the lower border of the cricoid cartilage; the lower opening of the larynx and the beginning of the trachea; (2) the lower end of the pharynx and the upper opening of the œsophagus; (3) the crossing of the omo-hyoid over the common carotid; (4) the level of the apex of the lung and to the summit of the arch of the subclavian artery. The *fourth thoracic* spine corresponds to the level at which the aorta reaches the spinal column, the trachea bifurcates, and posteriorly the apex of the lower lobe of the lung is found. It is on the same level as the root of the spine of the scapula. The *seventh thoracic* lies on a level with the inferior angle of the scapula. The *eighth thoracic* indicates the lower level of the heart and that of the central tendon of the diaphragm and the level at which the inferior vena cava passes through the diaphragm. The *ninth thoracic* marks the level at which the upper edge of the spleen is found in health, and at which also the œsophagus pierces the diaphragm. The *tenth thoracic* corresponds to the lower edge of the lung, the spot at which the liver comes to the surface posteriorly. The spines of the third to the ninth thoracic correspond to the heads of the fourth to the tenth ribs respectively. The *eleventh thoracic* is a guide to the normal situation of the lower border of the spleen and to the upper part of the kidney. The *twelfth thoracic* marks the lower limit of the pleura, the passage of the aorta through the diaphragm, and the situation of the pyloric end of the stomach, and is on a level with the head of the last rib. The *first lumbar* spine is on the line of the renal arteries and the pelvis of the kidney. The *second lumbar* spine corresponds to (1) the termination of the duodenum and the commencement of the jejunum; (2) the opening of the ductus communis choledochus into the intestine; (3) the lower border of the kidney; (4) the lower border of the pancreas; (5) the upper end of the root of the mesentery; (6) the point of origin of the superior mesenteric artery; (7) the commencement of the thoracic duct; (8) the commencement of the vena porta; (9) the termination of the spinal cord and the origin of the cauda equina; (10) the upper end of the receptaculum chyli. The *third lumbar* corresponds to the level of the umbilicus and the origin of the inferior mesenteric artery; the *fourth lumbar* spine marks the point of bifurcation of the abdominal aorta into the two common iliac arteries, and lies on a level with the highest part of the ilium; and, finally, the *fifth lumbar* spine is a little below the beginning of the inferior vena cava.

Direct cocainization of the spinal cord has recently been employed in surgery in operations on the lower abdomen, pelvis, and lower extremities. The injection into the subarachnoid space surrounding the cord is made through the space between the fourth and fifth lumbar vertebræ. To find this space, draw a line connecting the highest points of the crest of the ilium posteriorly. This will pass through the spine of the fourth lumbar vertebra. The point for injection is one centimetre below and one centimetre to the outer side of the point at which the transverse line crosses the vertebral spine in the median line.

THE THORAX.

THE thorax is that part of the body-cavity separated by the diaphragm from the abdomen below, but without complete separation from the neck above. Its bony walls are formed behind by the thoracic vertebræ, at the sides by the ribs, and in front by their continuations, the costal cartilages, and the sternum.

FIG. 173.



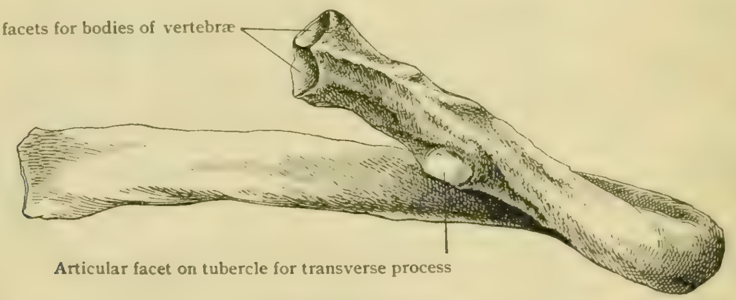
The bony thorax, anterior view.

THE RIBS.

The ribs, arranged as twelve pairs, are flat bars of bone, curved and twisted, which are attached behind to the spine and continued in front by the costal cartilages; they form the greater part of the bony walls of the thorax. The first seven pairs,

exceptionally eight, reach the sternum through their cartilages : hence they are called **sternal ribs**,[1] as distinguished from the remaining five pairs of **asternal ribs**.[2] Each cartilage of the next three joins that of the rib above it. The last two pairs have the cartilages ending free, and are termed **floating ribs.** Their complicated curves are best understood by studying them in place. Each rib (with certain exceptions to be detailed later) has an articular surface, the *head*, at the posterior end ; followed by a narrower *neck*, succeeded by an articular facet on the *tubercle* which rests on the transverse process of the vertebra. The first rib has an upper and a lower surface, an outer and an inner border ; the second faces in a direction intermediate to this and the following, which have an outer and an inner surface, an upper and a lower border. They are placed obliquely, the front end being lower than the hind one. The outline of the ribs is irregular, so that their declination is not due wholly to their position, but in part also to their shape. Thus, one in the middle of the series slants a little downward as far as the tubercle, then declines more sharply to a roughness near the tubercle known as the *angle*, and thence more gradually to the end. The main curve of such a rib is backward, outward, and downward as far as the angle, which marks a rather sudden change of direction, the course changing to one forward, slightly outward, and downward, until, as it reaches the front of the chest, it runs forward, downward, and inward. The external surface is vertical at the back and side and slants slightly upward in front. Bearing the declination of the rib in mind, it is evident that to accomplish this the rib must be twisted on itself, otherwise the upper edge would project in front.

FIG. 174.



Right fifth rib from behind.

The **head**[3] is an enlargement at the posterior end and on the outer surface,—*i.e.*, the one farthest from the cavity of the chest. It has an *articular surface* at the end facing inward and backward, divided into an *upper* and a *lower facet*, each for the body of a vertebra, by a transverse ridge, whence a ligament passes to the inter-vertebral disk. The lower facet is the larger, and is generally concave ; the upper is nearly plane. The head increases in size to the ninth rib and then lessens.

The **neck**[4] is compressed from before backward, smooth in front and rough for ligaments behind. The upper aspect has a sharp border, the *crest*,[5] for the superior costo-transverse ligament. The neck grows slightly longer in descending the series to the same level. The crest on the top of the neck is most developed in the sixth, seventh, and eighth ribs.

The **tubercle**[6] is an elevation beyond the neck on the posterior surface of the rib, bearing internally a round *articular surface* facing backward and, in most cases, downward, to rest on the transverse process ; beyond the articular facet is a rough knob for the external *costo-transverse ligament.*

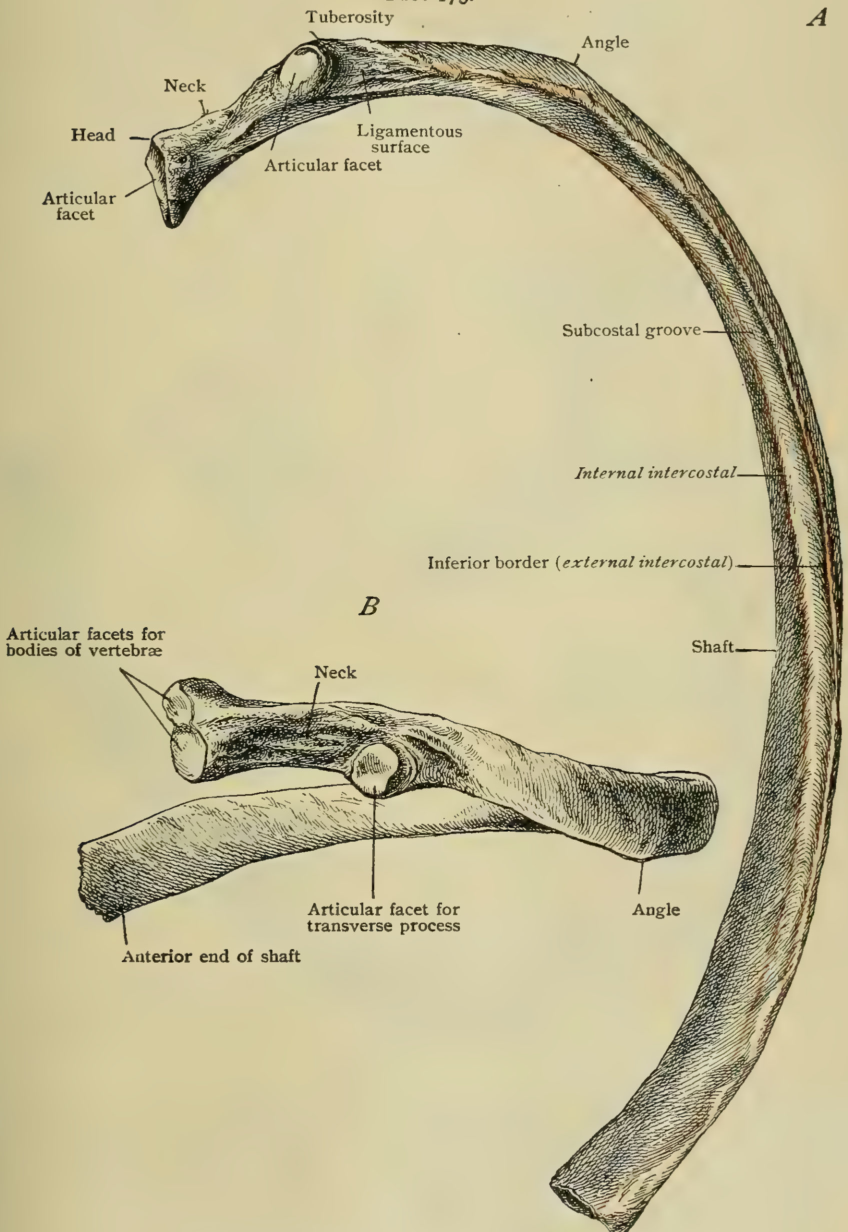
The **shaft**[7] is smooth inside, the surface being continuous with that of the neck. The *subcostal groove*[8] for the intercostal vein is best marked in the middle ribs, beginning at the tubercle and running forward, growing fainter, along three-quarters of the rib, just under cover of the lower border. The outer surface is rather irregular.

The **angle**[9] at which the shaft changes its direction is marked by a rough line on the posterior surface, some distance beyond the tubercle, receiving muscles from the system of the erector spinæ. The angle, which is not found in the first rib, is

[1] Costae verae. [2] Costae spuriae. [3] Capitulum. [4] Collum. [5] Crista colli. [6] Tuberculum [7] Corpus costae. [8] Sulcus costalis. [9] Angulus costae.

very near (one centimetre beyond) the tubercle in the second; it gradually recedes from the tubercle, being in the ninth and tenth about five centimetres distant. The angle is a little nearer in the eleventh, and is wanting in the last. The *twist* is greatest from the sixth to the ninth rib. Several of the upper ribs present near

FIG. 175.



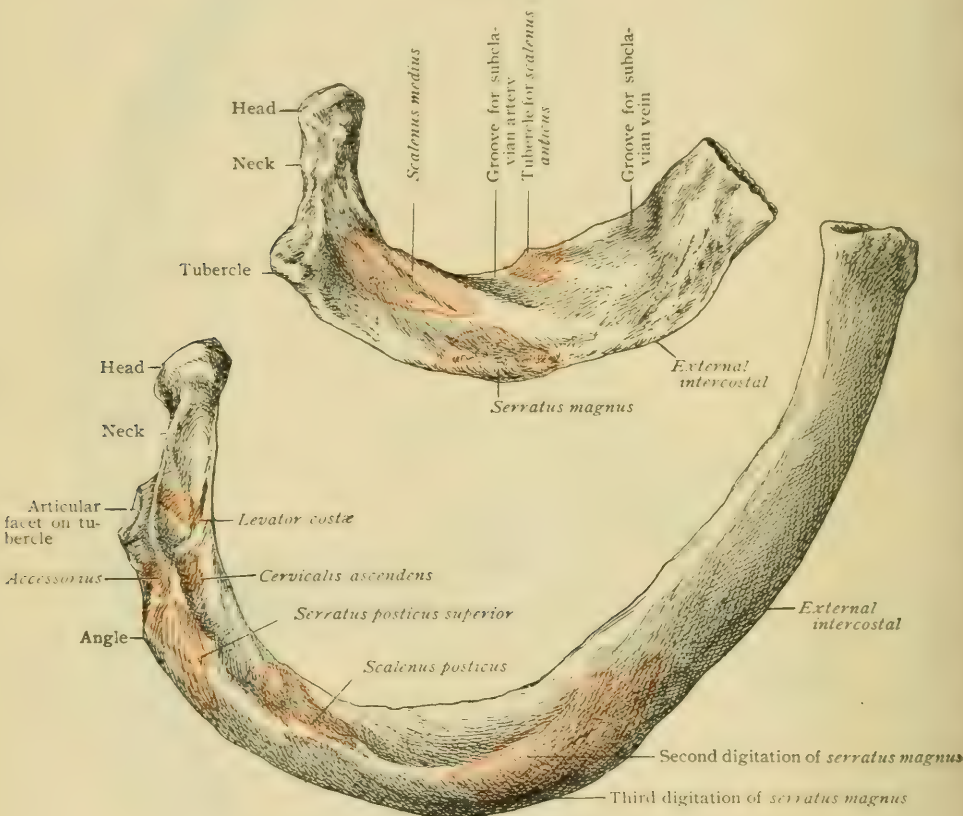
Right fifth rib: *A*, under surface; *B*, postero-lateral aspect.

the middle a rough impression for a point of the *serratus magnus*. The upper border of the shaft is thick and rounded behind, but thin near the front. The lower border is sharp where it overhangs the *subcostal groove;* less so in front. The *anterior end* of each rib is cupped to receive the costal cartilage.

The ribs increase in **length** from the first to the seventh or eighth, after which they decrease to the last, which is usually the shortest. The length of the last rib is, however, very uncertain, varying from one centimetre to perhaps fifteen centimetres or more. It often is longer than the first. The **curve** is comparatively regular in the first rib, after which the difference between the two ends becomes more marked, the curve being very pronounced behind and less so in front. The curve is much less throughout in the lower ribs; in fact, it decreases continually. The first rib is the broadest of all at the anterior end. There is a general, but not regular, increase from the second to the seventh rib, and a subsequent decrease. The fourth rib is relatively broad, the fifth narrow.[1]

Exceptional Ribs.—Certain of the ribs—the first, second, tenth, eleventh, and twelfth—present peculiarities which claim mention.

FIG. 176.



First and second ribs of right side, upper surface.

The **first rib** is flat, not twisted, with an outer and an inner border. The head is small and has but one facet, resting as it does on the first thoracic vertebra. The neck is small and flat like the body. The tubercle is very prominent. The *scalene tubercle* is a very small but, from its relations, important elevation on the inner margin of the upper surface, at about the middle, for the insertion of the scalenus anticus. It separates two grooves crossing the bone for the subclavian artery and vein. The posterior one for the artery is the more marked. There is a *rough impression* behind the latter near the outer border for the scalenus medius. There is no subcostal groove.

The **second rib** is intermediate in shape between the first and the rest. The roughness for the serratus magnus is very marked about the middle of the shaft.

[1] Anderson: Journal of Anatomy and Physiology, vol. xviii., 1884.

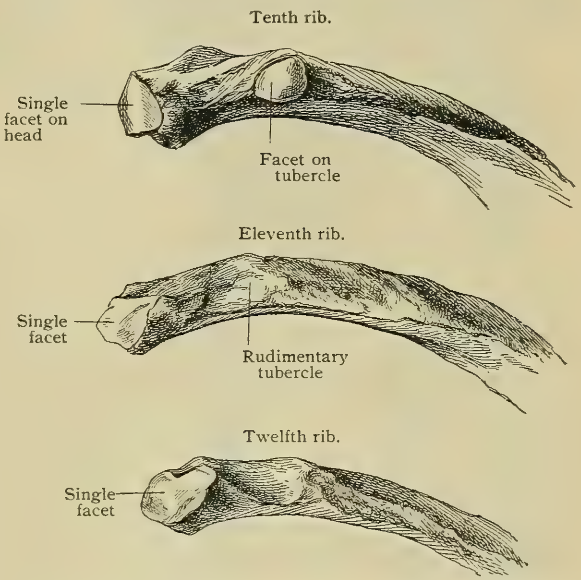
The **tenth rib** has usually only a single articular facet on the head ; it may or may not have a facet on the tubercle.

The **eleventh rib** has a single articular facet on the head ; the tubercle is rudimentary and non-articular ; the angle and the subcostal groove are slightly marked.

The **twelfth rib** has also a single articular facet on the head ; the tubercle is at most a faint roughness ; the angle and the subcostal groove are wanting.

Development.—The first centre for the shaft appears in the ninth week of fœtal life, and spreads so rapidly that by the end of the fourth month the permanent proportion of bone has been formed. At an uncertain period, probably before puberty, a centre appears for the head and another, except in the last two or three ribs, for the tubercle ; these unite presumably by the twentieth year.

FIG. 177.



Vertebral ends of tenth, eleventh, and twelfth ribs of right side from below.

Variations.—The number of ribs is often increased or diminished by one, generally by a change at the end of a region, as explained in variations of the spine (page 131). *Cervical ribs* occur by the costal element of the seventh cervical becoming free. In the lowest and most common grade it consists of a head, a neck, a tubercle, and a rudimentary shaft one or two centimetres long, ending free. In the next grade it is longer, and its end, perhaps continued in cartilage, rests on the first rib. Sometimes it fuses with the first rib, which then becomes bicipital, as is normal in certain whales. In the third grade, which is very uncommon, it resembles a small first rib, reaching the sternum. A cervical rib has been seen more than once with the transverse foramen persisting. The explanation of this condition is given under ossification of the vertebræ. When a cervical rib reaches the sternum, the next rib is usually attached to the side of the manubrium by a broad cartilage, fusing with that of the cervical rib. The rib of the eighth vertebra has been seen to end like an ordinary second rib. It is also very rare to have only twelve pairs of ribs, of which the first is cervical. There may be thirteen ribs by the addition of the costal element of the first lumbar. This may be so small as to present no rib-like feature, or it may resemble an ordinary twelfth rib. In cases of an extra rib from this source the twelfth rib is usually uncommonly long. Very rarely the first true thoracic rib is imperfect, being continued in ligament to the sternum, joining the shaft of the second rib, or even ending free. A bicipital rib may occur also by the fusion of the first thoracic with the second beyond the tubercles. The resulting plate later subdivides, to be continued by two normal costal cartilages. Ribs sometimes divide, generally near the front. The parts formed by such cleavage are continued by costal cartilages which usually reunite, so that a foramen is formed which is bounded laterally or externally by bone, mesially by cartilage. This occurs most commonly in the third and fourth ribs, especially in the latter.

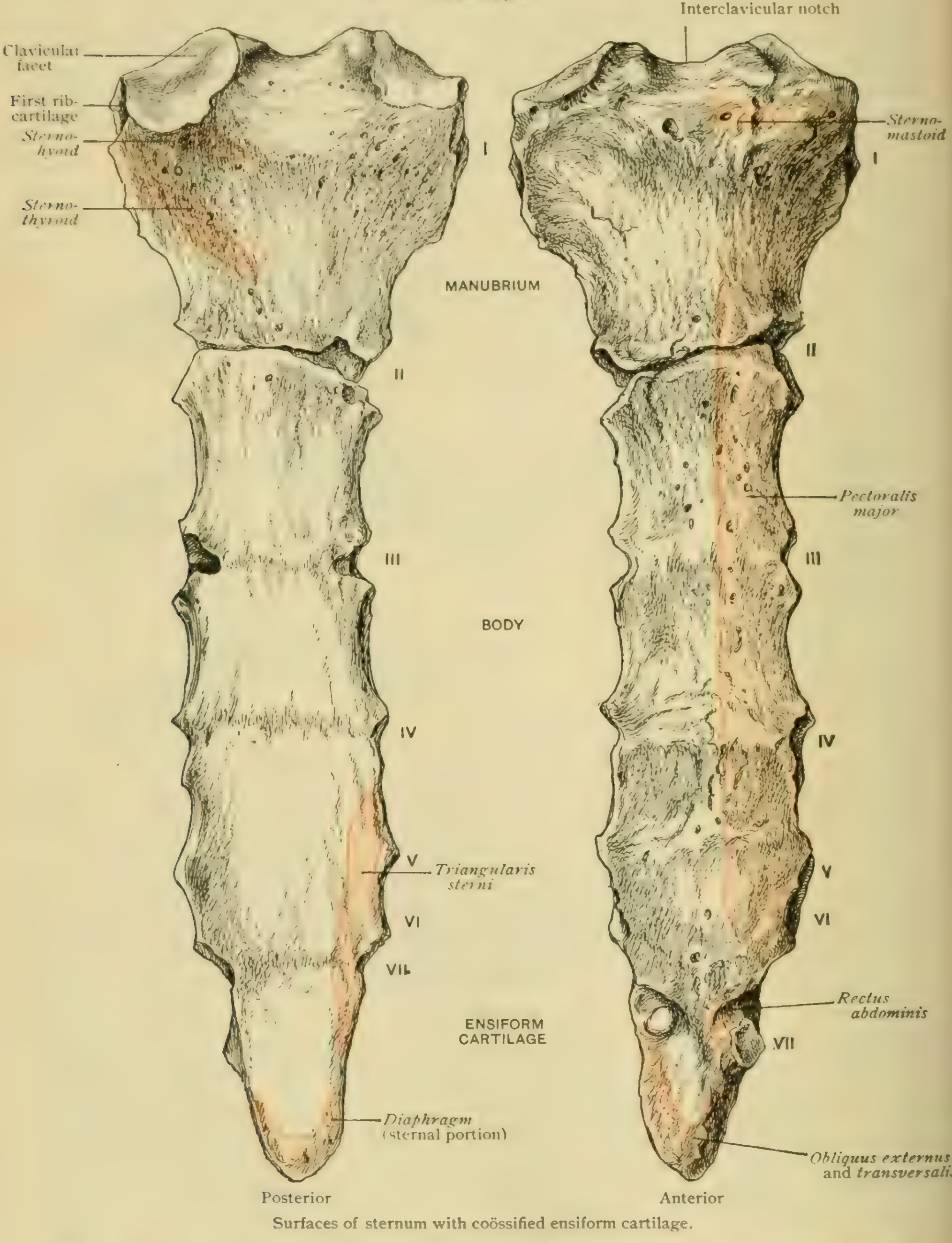
THE COSTAL CARTILAGES.

The costal cartilages[1] continue the ribs, the first seven going directly to the sternum, the next three each to the one above it, and the last two ending free. They grow longer from the first to the seventh, sometimes to the eighth. The last two

[1] Cartilagines costales.

cartilages are short and pointed. There is occasionally a projection downward from the fifth, at its most dependent point, which articulates with the sixth. Usually there is a similar projection on the latter for the seventh. The eighth, ninth, and

FIG. 178.



Surfaces of sternum with coössified ensiform cartilage.

tenth cartilages have usually their chief connection with the one above, not through their ends, but through similar facets. As to direction : the first cartilage descends, the second is horizontal, the third rises very slightly, and the fourth is the first to fall and then rise. This change of direction occurs in each to the ninth or tenth carti-

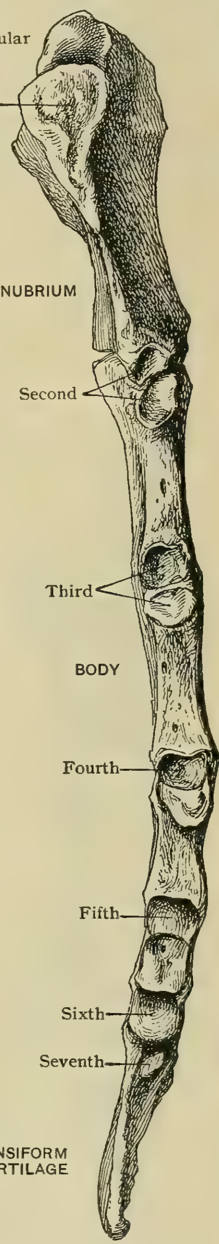
lage, the falling portion becoming always relatively shorter and the rising longer. The last two cartilages continue the line of their ribs, having no rising portion. It is not uncommon to find eight cartilages joining the sternum. Tredgold found this condition in ten per cent. of white men. It is very much more frequent in negroes and in other dark races.[1] It is said to occur more often on the right side.

THE STERNUM.

The adult sternum consists of three flat median plates, the two former being bone, the last largely cartilage,—namely, the *presternum* or *manubrium*, the *mesosternum*, *gladiolus*, or *body*, and the *metasternum* or *ensiform cartilage*.

The **manubrium**[2] is broad in mammals having clavicles, to which it gives support at the upper angles. In man it is irregularly quadrilateral, with the angles cut off, broad above, narrower below, the greatest breadth equalling or exceeding the length. It is concave behind, but in front it is convex from side to side and slightly concave from above down. The upper border is concave in the middle, forming the bottom of the *interclavicular notch*.[3] On each side of this, in the place of a corner, is a concavity for the sternal end of the clavicle. This depression[4] is more on the top than on the side of the sternum, and usually encroaches more on the back of the bone. It is concave from within outward and may, or may not, be slightly concave from before backward. The facet is coated with articular cartilage. Just below the joint, the side of the manubrium projects outward to meet the cartilage of the first rib. This is the widest part of the first piece, the border then slanting inward to the lower angle, which also is cut off by a notch for the second costal cartilage, which is received between it and the body. The lower border, separated from the mesosternum by fibro-cartilage, projects a little forward into a transverse ridge, always to be felt in life, which indicates the level of the second costal cartilage.

FIG. 179.



Right side of sternum.

The oblong **body**, or **gladiolus**,[5] ossifying originally in four pieces, one above another, varies considerably in shape. It is generally slightly concave behind and nearly plane in front, but it may be convex or even concave. The greatest breadth is below the middle, whence the borders slant inward to the lower end, the narrowest part, where it joins the ensiform cartilage. The sides of the body present alternately smooth concavities opposite the spaces between the costal cartilages and articular facets for the latter. To understand the position of these articular facets, we must recall the composition of the mesosternum as consisting of four pieces. The second cartilage reaches the junction of the manubrium and the body ; the third, that of the first and second pieces of the body ; the fourth, that of the second and third pieces ; the fifth, that of the third and fourth pieces. The two remaining sternal ribs send their cartilages to this fourth piece of the body ; the sixth to the side, and the seventh to the lower angle, or even the

[1] Journal of Anatomy and Physiology, vol. xxxi, 1897. Lamb : Nature, 1888.

[2] Manubrium sterni. [3] Incisura jugularis. [4] Incisura clavicularis. [5] Corpus sterni.

lower edge. The first and second pieces of the body are about equal in length ; the third is shorter, and the fourth still more so ; hence the fifth, sixth, and seventh cartilages end very close together, especially the two last.

The **ensiform cartilage**,[1] or **xiphoid process**, more or less bony in middle life, is a flat plate with a rounded end, not rarely bifid. It is fastened to the lower end of the body in such a way that their posterior surfaces are continuous, but that the ensiform, being thinner, is overlapped by the ends of the seventh cartilages ; its front is therefore at a deeper level than that of the body. The size and shape of the ensiform cartilage are very uncertain ; usually the tip projects somewhat forward.

Differences due to Sex.—The body of the male sternum is both absolutely and relatively longer than that of the female. This is in accordance with the greater development of the male thorax. The following table gives the actual size, according to the writer[2] and to Strauch.[3]

	Dwight. Men. Centimetres.	Dwight. Women. Centimetres.	Strauch. Men. Centimetres.	Strauch. Women. Centimetres.
Manubrium	5.37	4.94	5.049	5.056
Body	11.04	9.19	11.014	9.059
Total	16.41	14.13	16.063	14.115

Hyrtl gave a rule for determining the sex, that the manubrium of the female exceeds half the length of the body, while the latter in the male is at least twice as long as the manubrium. A study of 342 sterna, of which 222 were male and 120 female, confirmed Hyrtl's law for the mean ; since, however, approximately forty per cent. of the cases were exceptions, it is clearly worthless to determine the sex in any given case. Probably the law would be correct if we had to do only with well-formed sterna, but the body varies greatly. It is easy to recognize a typical male or female sternum. The former has a long, regular body, the lower pieces of which are well developed, separating the lower cartilages of the true ribs. The latter has a shorter and relatively broader body, the lower parts of which are poorly developed, so that the cartilages are near together, and the seventh ones of the two sides almost, or quite, meet below the body in front of the base of the ensiform.

Fig. 180.

Sternum, showing foramen due to imperfect union of lateral parts.

Variations.—The very rare cases of fissure of the sternum, and the not uncommon ones of perforation in the median line, represent different degrees of arrest of development. The lower half of the sternum is sometimes imperfectly developed. We have described a case in a negress in which there was but little and irregular ossification below the fourth costal cartilage. A very rare anomaly is that of the manubrium being prolonged to the insertion of the third costal cartilages, as occurs usually in the gibbons and occasionally in other anthropoid apes.

The *suprasternal* bones, very rarely seen in the adult, are a pair of rounded bones compressed laterally, about the size of peas, placed on the top of the manubrium at the posterior border just internal to the sterno-clavicular joint. They are presumably the tops of the lateral cartilaginous strips forming the sternum, in which they are normally lost. They are regarded as representing the *episternum* of lower vertebrates.

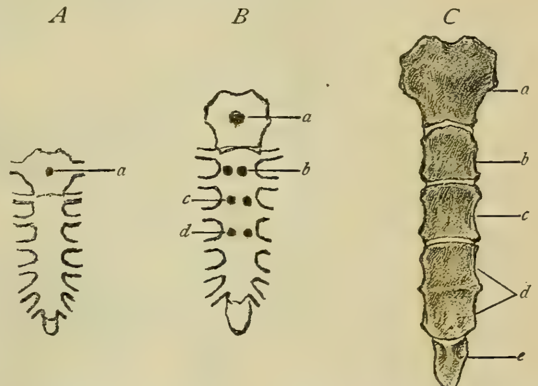
[2] Journal of Anatomy and Physiology, vol. xxiv., 1890. [3] Inaug. Disser., Dorpat, 1881.

[1] Processus xiphoideus.

Development and Subsequent Changes.—The cartilaginous bars representing the ribs in the early embryo end in front in a strip connecting them from the first to the ninth, which approaches its fellow above and recedes from it below. The union of these two strips, which begins above, forms the future sternum as far as the ensiform cartilage. Thus at this early stage there are nine sternal ribs. While the mesosternum is forming by the union of the lower part, a portion of the ninth strip separates itself from the rest to fuse with its fellow for the ensiform cartilage, and the remainder of the ninth joins the eighth, which, as a rule, itself later recedes from the sternum.

The original cartilaginous strips having fused, points of ossification first appear in the manubrium about the sixth month of fœtal life. There is one chief one and a varying number of small ones variously disposed. Sometimes it ossifies in a larger upper and a smaller lower piece. In the latter months, before birth, several points appear in the mesosternum. The first piece generally has a single centre, those below two in pairs. **At birth** one usually finds ossification begun in the first three pieces of the body. The centre for the last piece of the body begins to ossify at a very variable time. We have seen bone in it at thirteen days and have found none at seven years. Perhaps three years is not far from the average. The centre, or centres, for this last piece of the body are placed in its upper part. Its cartilage is directly continuous with that of the ensiform, the line of demarcation being determined by the difference in thickness, the ensiform being thinner and continuing the plane of the posterior surface. Thus, the lower part of the last piece may continue cartilaginous for a considerable time. A centre in the ensiform is sometimes seen at three, but may not come for several years later. The four pieces of the mesosternum join one another from below upward, the union being completed on the posterior surface first. The process is extremely variable. The only points regarding which we are certain are that it is more rapid than is usually stated and that the body is almost always in one piece at twenty. The fourth piece of the body joins the third at about eight, the third joins the second at about fifteen, and the second unites with the first usually at eighteen or nineteen. We once saw all four pieces distinct at eighteen, but in one or two instances only have we found the body incomplete after twenty. The amount of bone in the ensiform at twenty is still small. The adult condition, except that the ensiform gradually becomes wholly bone, may persist to extreme old age. The ensiform often joins the body after middle age, rarely before thirty. The union of the manubrium and the body is rare, and appears to be the result of a constitutional tendency rather than of age, as in our observations we have repeatedly found it under fifty, and have seen all three pieces united at twenty-five. The different pieces are more apt to fuse in man than in woman.

FIG. 181.



Ossification of the sternum. *A*, at sixth fœtal month; *a*, centre for manubrium. *B*, at birth; *a*, for manubrium; *b*, *c*, *d*, for segments of body. *C*, at about ten years; *a*, manubrium; *b*, *c*, *d*, segments of body; *e*, ensiform cartilage.

ARTICULATIONS OF THE THORAX.

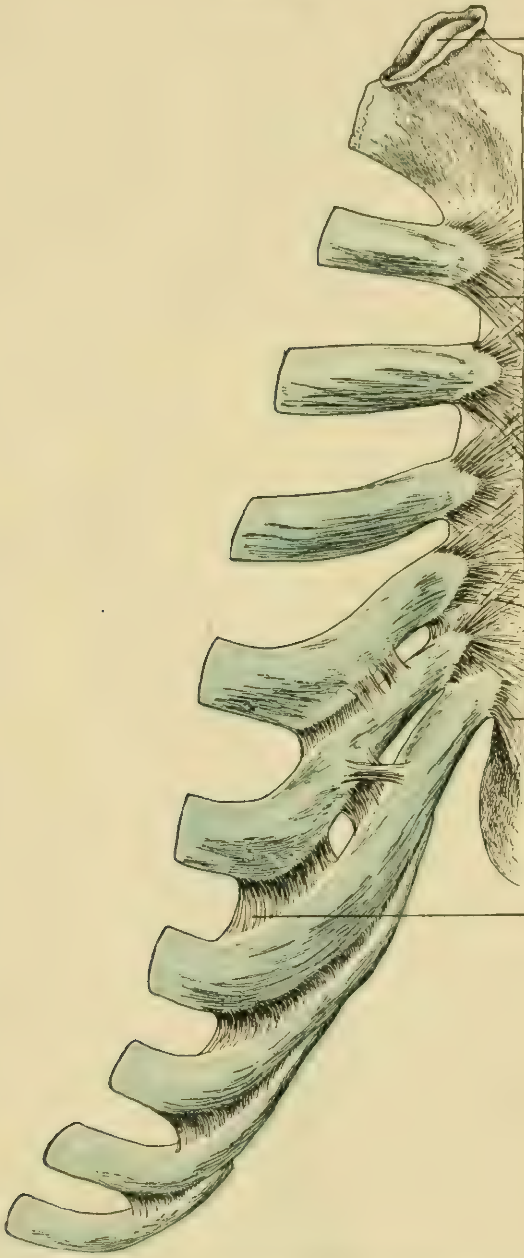
The joints uniting the bones taking part in the formation of the bony thorax constitute two general groups, the *Anterior* and the *Posterior Thoracic Articulations.* The former include the joints between the pieces of the sternum, those between the sternum and the costal cartilages, and those between the costal cartilages; the latter, or the *costo-vertebral articulations*, include those between the vertebræ and the ribs.

THE ANTERIOR THORACIC ARTICULATIONS.

These include three sets :

1. The **Intersternal Joints**, or those uniting the segments of the sternum ;

FIG. 182.



The sternum and costal cartilages from before.

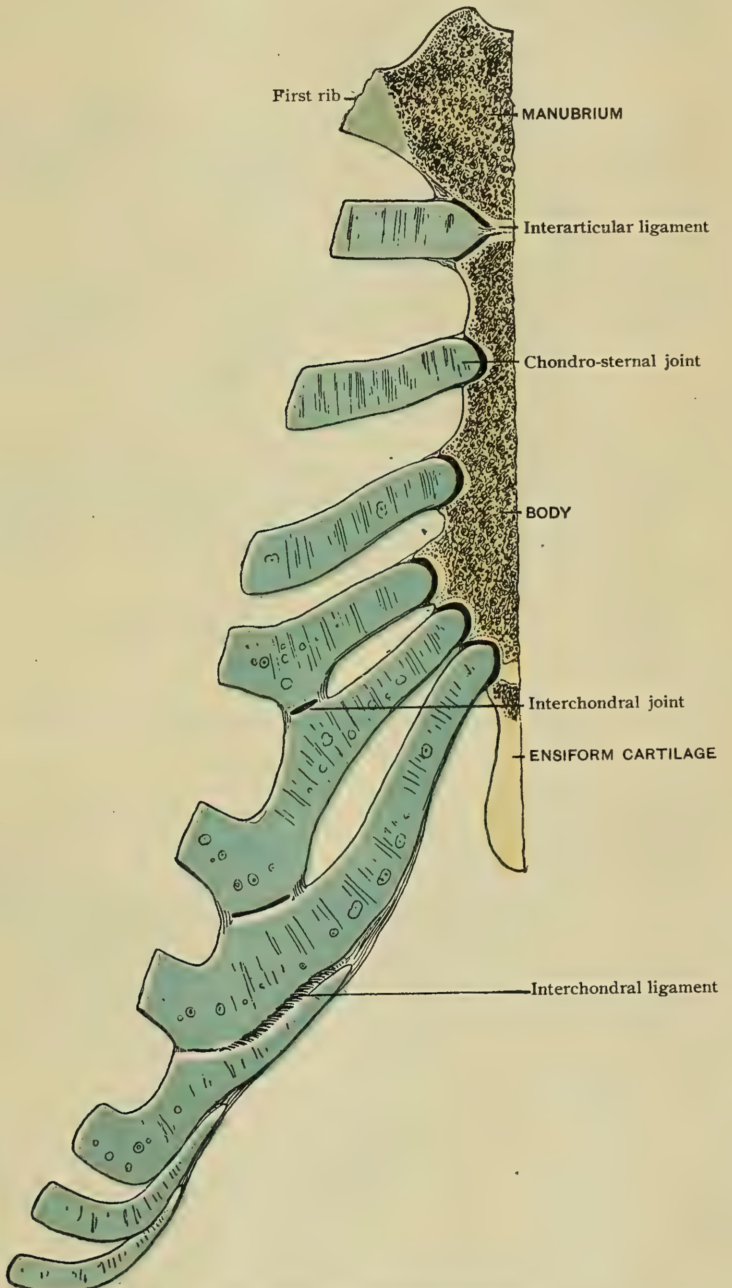
2. The **Costo-Sternal Joints**, or those uniting the ribs by means of their cartilaginous extensions with the sternum ;

3. The **Interchondral Joints**, or those uniting certain of the costal cartilages with one another.

THE INTERSTERNAL JOINTS.

While the manubrium and the four pieces of the body, or sternebræ, are still separate ossifications in a common strip of cartilage, the structure is greatly strength-

FIG. 183.



Longitudinal section through sternum and costal cartilages.

ened by the thick periosteum, reinforced by the radiating bands from the costal joints and longitudinal fibres before and behind. When the body has become one piece it is separated from the manubrium by the persisting cartilaginous strip. The

strengthening bands require no further description. A cavity is often found in the cartilage, making a typical half-joint. At what time it appears is unknown. Sometimes it is so developed that the joint is practically a true one, with articular cartilage; this exceptional arrangement is more common in women than in men, being especially adapted to the female type of respiration. The cartilage persisting between body and ensiform is strengthened in a similar manner. A cavity rarely occurs in the cartilage, which, on the contrary, often undergoes ossification.

THE COSTO-STERNAL JOINTS.

The first costal cartilage joins directly, without interruption, the lateral expansion of the sternum; the following costal cartilages articulate at the points already mentioned by synovial joints. Those that come between different sternebræ—that is, from the second to the fifth—often have the joint subdivided by a band into an upper and a lower half. This is usual in the joint of the second cartilage; progressively rare as we descend. The sixth and seventh cartilages frequently have no true joint.[1] Each of these joints is enclosed by a capsule, the front and back fibres of which radiate over the sternum.

THE INTERCHONDRAL JOINTS.

The seventh, eighth, ninth, and tenth costal cartilages have each an articulation by a true joint on the projections above described with the one above it. There is a connection between the fifth and sixth cartilages; usually on the right, very frequently on the left.[2] This is, as a rule, also a true joint, but the cartilages may be merely bound together by bands of fibres. The joint on the right side is almost always a true one. The ends of the eighth, ninth, and tenth cartilages are joined by fibrous tissue to the cartilage above.

The **costo-xiphoid ligament** is a band extending from either side of the base of the ensiform to the lower border and, perhaps, the front of the seventh cartilage near its end.

THE COSTO-VERTEBRAL ARTICULATIONS.

The joints between the ribs and the spine are in two series: an inner, or *Costo-Central*, between the *heads* of the ribs and the *bodies* of the vertebræ; an outer, or *Costo-Transverse*, between the *tubercles* and the *transverse processes*.

The Costo-Central Joints.—The head of the rib is received in a hollow articular fossa formed by a part of two bodies and the disk between them. Although as a whole concave, it may in a typical case be further analyzed. The lower half of the socket is convex from above downward, fitting into the hollow at the lower part of the joint of the rib; the upper part is about plane, looking downward and outward, with the upper border considerably overhanging the joint. These two facets have each a synovial capsule and are separated by an *interarticular ligament*,[3] a band running from the ridge on the head of the rib to the posterior part of the intervertebral disk. In the fœtus before term it extends across the back of the disk to the head of the opposite rib.

The front of the capsules is strengthened by the *anterior costo-vertebral ligament*,[4] which is a series of radiating fibres from the head to both vertebræ and the intervening disk, not clearly separable into three bands. These *stellate ligaments* (Fig. 184) are least developed in the upper part of the thorax. The strongest collection of fibres is to the lower vertebra. The joint of the first and last two ribs is not subdivided; that of the tenth is uncertain. Strong fibres pass from the head of the first rib to the seventh cervical vertebra. Few or no fibres from the last rib reach the body of the eleventh thoracic. The lower fibres are made tense when the rib is raised and the upper when it is depressed.

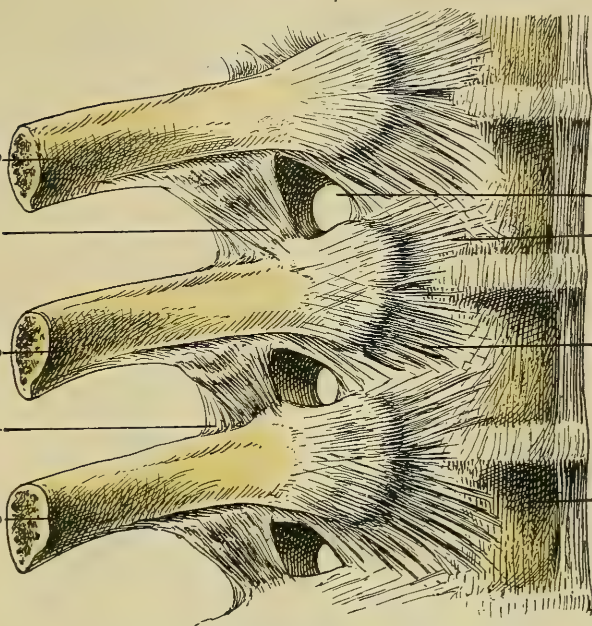
The Costo-Transverse Joints.—The articular surfaces of the tubercles,

[1] Musgrove: Journal of Anatomy and Physiology, vol. xxvii., 1893. [2] Fawcett: Anat. Anzeiger, Bd. xv. Bardeleben: ibid.

[3] Lig. capituli costae interarticulare. [4] Lig. capituli costae radiatum.

convex vertically, are received into the hollows on the facets of the transverse processes. The cavities are deepest in the upper part of the thoracic region, but the facet on the first transverse process is nearly plane. In the lower part of the region

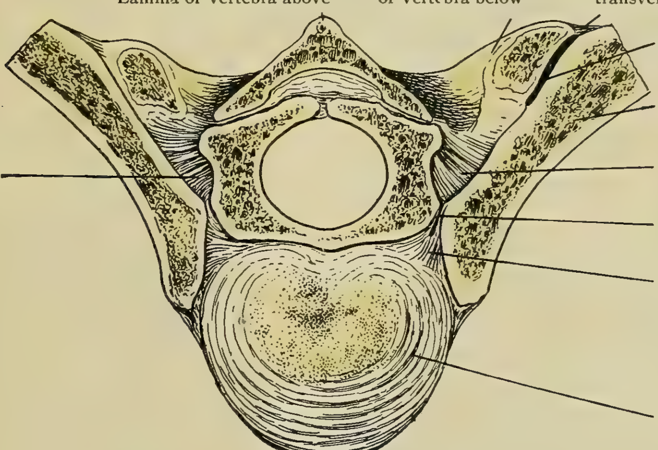
FIG. 184.



Ligaments uniting ribs with spine, from before.

these cavities are smaller and less concave, allowing freer motion. There is none for the twelfth rib, and but a poor one, if any, for the eleventh. There are three *costo-transverse ligaments*: the *posterior*, the *middle*, and the *superior*. The *pos-*

FIG. 185.



Transverse section through intervertebral disk and ribs.

terior[1] are strong bands running outward from the tips of the transverse processes to the rough part of the tubercle beyond the joint. The *middle*[2] are strong short fibres connecting the front of the transverse process and the back of the neck of the

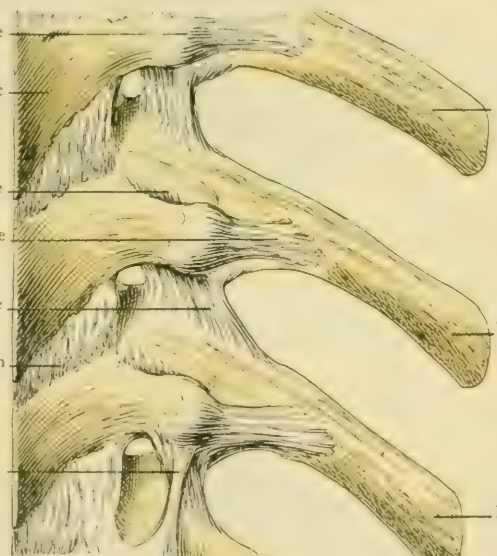
[1] Lig. costotransversarium posterius. [2] Lig. colli costae.

rib between the head and the tubercle. Those for the last two ribs are small, that for the twelfth springing from the accessory tubercle. The *superior costo-transverse ligaments*[1] are thin bands, passing downward and a little inward from the under side of the transverse processes to the crest on the upper edge of the neck of the rib below. Those of the first and last two ribs are of little account. This band becomes tense when the rib is depressed and carried inward; the inner fibres are tense when the rib is raised. The outer fibres fuse with the front surface of the posterior intercostal aponeurosis. Weaker and inconstant bands of the same general direction are described behind these. The fibres of the aponeurosis are particularly strong between the last two ribs. A special band of the same series runs from the transverse process of the first lumbar upward and outward to the last rib. The movements of the ribs are described with those of the thorax (page 165).

THE THORAX AS A WHOLE.

The thorax is a cage with movable walls capable of expansion. In shape it is an irregular truncated cone, much deeper behind than in front and broader from side to side than from before backward. The thoracic vertebræ form the posterior

FIG. 186.



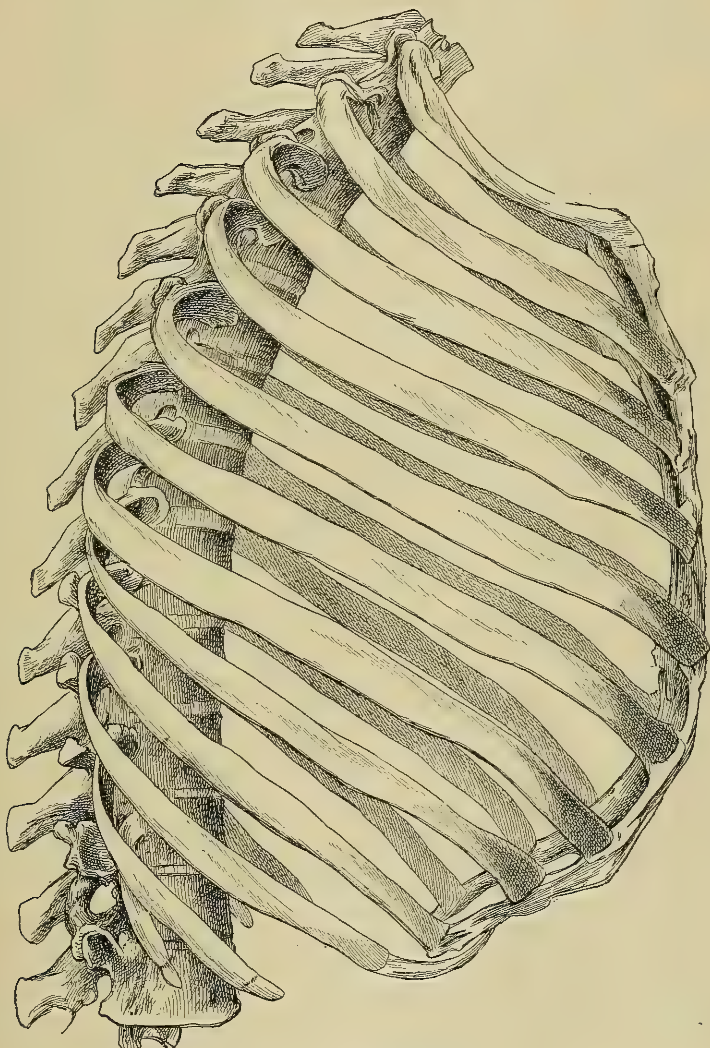
Ligaments uniting ribs with spine, from behind.

boundary; the sternum, including the very beginning of the ensiform cartilage, the anterior. The inlet, or upper boundary, is an imaginary plane slanting downward and forward from the top of the first thoracic vertebra to that of the sternum, and bounded laterally by the inner borders of the first rib. The inferior boundary, made by the diaphragm, does not exist in the skeleton. Suffice it to say that the dome-like disposition of the diaphragm makes the abdomen much larger and the thorax much smaller than one would expect from the skeleton alone. The thorax of the living presents a fairly well-defined posterior surface, while the lateral ones pass insensibly into the anterior; the upper part is hidden by the shoulder-girdle and arm. The line of the angles of the ribs marks the limits of the back and sides. The inside of the thorax is heart-shaped in horizontal section. The spine projects into it behind, and the ribs recede from this on either side. As the bodies of the vertebræ are larger in the lower part, the projection into the thorax is greater; but as the area of the section is much larger, the effect is less striking. The distance from front to

[1] Lig. costotransversarium anterius.

back in the median line is least at the top. It increases at once, owing to the backward bend of the spine and the forward slant of the sternum, reaching the maximum at about the middle of the thorax. It decreases slightly below, owing to the forward sweep of the spine, but the position of the lower end of the sternum is so uncertain that this is very variable. The breadth of the thorax increases very rapidly, reaching nearly the maximum where the third rib crosses the axillary line. Below this it increases a little, being greatest where the fifth rib crosses the same

FIG. 187.



The bony thorax, lateral view.

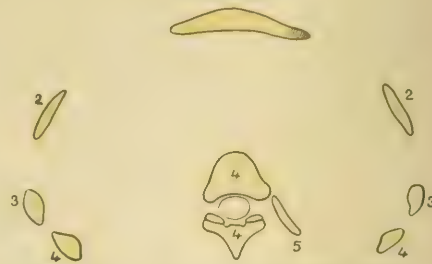
line. It then continues very nearly the same with some slight diminution below. The greatest length of the thoracic framework is in the axillary line, the lowest point being the cartilage of the tenth or eleventh rib, which in the male may nearly reach the crest of the ilium. The downward slant of the ribs and the rise of most of the cartilages make the study of horizontal sections at first very confusing. The relations at certain levels must be somewhat conventional, for the variations are very great, depending on figure, age, health, position, and the stage of the respiratory movements. Two levels must be taken as standards, subject to these corrections.

The top of the sternum is on a level with the disk between the second and third thoracic vertebræ ; the junction of manubrium and body of sternum is on a level

FIG. 188.

Transverse section through thorax at level of third thoracic vertebra. (*Braune.*)

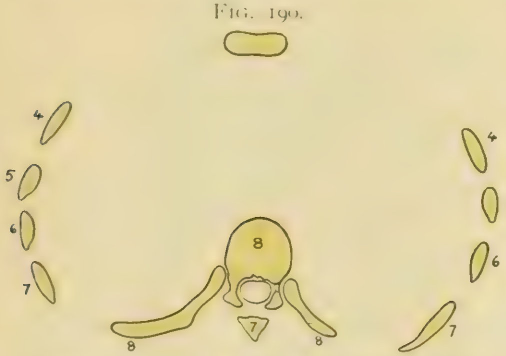
FIG. 189.



Transverse section at level of fourth thoracic vertebra. (*Braune.*)

with the top of the fifth thoracic vertebra. Less accurate, but still useful, is a third level : the lower end of the body of the sternum is opposite the ninth thoracic vertebra. Accompanying diagrams, taken from Braune, show the variations of size, form, and relations at different levels (Figs. 188 to 191).

FIG. 190.



Transverse section at level of eighth thoracic vertebra. (*Braune.*)

The breadth of the intercostal spaces is very different in diverse parts. Between the tubercles and angles it is pretty nearly the same throughout, but the last two spaces are a little broader. The first two spaces are much the broader at the sides and in front. They are broad near the sternum as far down as the fifth cartilage. At the sides the ribs are very close together, from the fourth to the ninth often almost in contact. The lowest spaces are again broader.

The Thorax in Infancy and Childhood.—At birth the thorax is relatively insignificant. The sternum is small and undeveloped in the lower part. The ribs are more horizontal. The top of the sternum is opposite the body of the first thoracic vertebra. In the course of the first year it lies opposite the upper part of the second, and at five or six has reached its definite level opposite the disk between the second and third thoracic vertebræ. The lower part of the sternum is undeveloped, and the ribs do not fall so low at the sides. The want of breadth is very striking, while in the adult, throughout the chest below the level of the second costal cartilage, the antero-posterior diameter is to the transverse as 1 to 2½, or as 1 to 3 ; at birth it is as 2 to 3. We have found it at probably three years as 1 to 2 ; at five or six the thorax has nearly reached its permanent shape.

FIG. 191.

Transverse section at level of eleventh vertebra. Shaded areas (6, 7) are sections of costal cartilages. (*Braune.*)

Differences due to Sex.—The whole structure is lighter in women, but the

chief differences in the proportions appear below the third rib. The manubrium is as large, relatively to the height, in one sex as the other, although the mesosternum in women, especially its lower part, is less developed ; hence the ends of the cartilages of the lower sternal ribs are crowded together, and those of the seventh often meet below the sternum, in front of the ensiform, thus practically lengthening the body. The effect of this is that the relations of the viscera to the walls are not so different in the sexes as one would expect.[1] The floating ribs are small in women and do not approach the pelvis so closely as in the male. The antero-posterior diameter of the female chest is to the transverse as 1 to 2½ (subject to variation), thus more resembling the proportions of the child.

THE MOVEMENTS OF THE THORAX.

The motions permitted by the following joints are to be considered separately, although their interdependence is to be remembered. First, the joints of the vertebral ends of the ribs, the costo-central and the costo-transverse being taken together ; second, those between the manubrium and gladiolus ; third, the costo-sternal and interchondral joints ; fourth, as modifying these, flexion and extension of the spine ; and fifth, the elasticity of the ribs and cartilages.

Motions in the Costo-Vertebral Joints.—These vary greatly in different parts of the column. The first rib moves as a hinge on a fixed axis running outward, backward, and a little upward through the joint on the body of the vertebra and that on the transverse process. If this axis were strictly transverse, the rising of the front of the rib would increase only the antero-posterior diameter of the thorax, as the motion occurs in a plane at right angles to the axis. Since, however, the axis is oblique, a plane at right angles to it extends forward and outward, and motion in it thus increases also the transverse diameter of the chest. The shape of the first rib is such that this transverse increase amounts to little or nothing, but this principle comes into play with the longer ribs. The joint of the second rib is practically similar, except that the outer end of the axis at the tubercle is farther back, so that the plane of motion slants more outward and the lateral expansion gained by raising the second rib is more marked independently of the greater length of that rib. With the third rib, usually, an important modification begins ; the outer end of the axis is not fixed, for the tubercle slides on the transverse process. The changes in the facets on the transverse processes have been described ; it appears that, as we descend the spine, they are so placed and so shaped as to allow this movement more and more freely. Thus, in the middle of the thoracic region the outer end of the axis of rotation is so movable that the motion is to be decomposed into two,—namely, one on the axis already described through the head and the tubercle, and another on an antero-posterior axis passing through the head of the rib and the joint between its costal cartilage and the sternum. At the eighth rib of the dissected spine a new motion appears, which becomes much more extensive in the succeeding ones. The ligaments connecting the tubercle and neck to the transverse process are less tense, and it is possible to move the tubercle a little forward from its socket ; in the lower joints the rib can be moved upward, downward, forward and backward, and circumducted. These motions are particularly free at the last two thoracic vertebræ. Motion backward is checked by contact with the transverse process ; forward, by the posterior and middle costo-transverse ligaments ; upward motion of the last two ribs by the particularly strong bands of fascial origin described with the ligaments ; downward motion by the intercostal structures. An important deduction from this is that the last ribs can be pulled downward and backward, so as to fix the posterior costal origin of the diaphragm.

Motions in the Intersternal Joints.—The joint between the manubrium and the body of the sternum admits of motion on a transverse axis, which is free in the young, but much restricted or abolished in the old. At rest, the two parts form a slight angle open behind. This is effaced by the forward motion of the body on

[1] Henke: Arch. für Anat. u. Phys., Anat. Abtheil, 1883.

the manubrium, but in no case is an entering angle formed in front. A slight twisting may also occur in this joint in the young. In these motions the second costal cartilages follow the manubrium. The motions at the inconstant joint between the sternal body and the ensiform process are necessarily indefinite; they appear to consist chiefly of a drawing in of the ensiform.

Motions in the Costo-Sternal and the Interchondral Joints.—On the dissected preparation the second cartilage can be moved up and down, forward and backward, and circumducted; these motions, however, are very slight. In the succeeding joints the same motions are more and more free as we descend. The lower cartilages of the true ribs from the fifth to the seventh, or to the eighth, inclusive, should the latter meet the sternum, move in a somewhat similar manner, but nearly as in one piece. The motion on an antero-posterior axis is most free. The joints between the costal cartilages are very lax, and the surfaces are so placed that the lower one slides forward on the upper. The advantage of these joints is that the lower ribs and the thorax give and receive support, while greater freedom of motion is possible than would be the case were they of one piece. *Flexion* and *extension* of the spine modify these motions. The more the spine is flexed the more the upper ribs in particular are depressed, and the more it is extended the more they are raised, independently of any motion in the joints. Thus, when the chest is fully inflated the spine is always strongly extended.

The *elasticity* of the ribs and cartilages, particularly of the latter, exercises an important, but indefinite, influence on all motions which does not admit of accurate analysis. Even the ribs (except in the old) are not rigid bars, and, especially in forced inspiration, there is a pull upon them increasing their convexity. Moreover, the walls of the chest adapt themselves to the surface of the lungs and to abnormal contents of the thorax, so that certain conditions are marked by particular forms of thorax.

It follows from the above that the nature of the respiratory movements cannot be deduced solely from the movements of each set of joints considered separately. The soft parts connecting them alone modify greatly the freedom of motion. Braune has shown that the motion of the ribs is much limited by the sternum, and that if the gladiolus be divided into its original pieces and the cartilage above it cut through, the thorax can be more fully inflated. Beyond question in forced inspiration the sternum is raised, thus increasing the antero-posterior diameter; since the ribs at the same time swing upward and outward, the transverse diameter is likewise increased.

Surface Anatomy.—The sternum is always to be felt in the middle line. The suprasternal notch is filled up to a large extent by the interclavicular ligament. The angle between the manubrium and the body varies considerably, but it is always easily recognized by a cross-ridge. The ensiform cartilage is at a deeper level and overhung on each side by the costal arch. The front of the chest on each side is covered by the pectoralis major, making it hard to feel the ribs, except at the borders of the sternum. At the side they are easily felt to near the top of the axilla, where the third can be recognized.

The upper ribs are concealed by thick muscles, especially between the spine and the angles. The scapula covers them from the second to the seventh, with considerable variations. The first rib cannot be felt except where its cartilage joins the sternum. To count the ribs, begin with the second at the junction of the manubrium and body of the sternum. There is no possibility of error, for the rare cases of the manubrium reaching to the third cartilage may be disregarded; feel the third and fourth cartilages below it, and then carry the finger downward and outward across the chest. The twelfth rib may be too small to be made out. It is not safe to begin counting from below, for the error of mistaking the eleventh rib for the twelfth has led to opening the pleural cavity in an operation in the lumbar region. The nipple is said to be usually over the fourth intercostal space some two centimetres external to the cartilage, but it is very variable, especially in women, and should never be used as a starting-point for counting the ribs. The width of the intercostal spaces at different parts is of obvious importance, but has been described elsewhere (page 164).

PRACTICAL CONSIDERATIONS.

The bony and cartilaginous thorax is made up of the ribs, sternum, costal cartilages, and thoracic vertebræ, and varies in shape as a result of several influences. The slightly larger circumference of the right side of the chest as compared with the left side is probably due to the greater use of the right upper limb, and may be accepted as physiological. Increased circumference of the left side, therefore (in a right-handed person), should indicate careful examination of the spine (for lateral curvature) and of the thoracic viscera.

In *pigeon-breast* the sternum protrudes together with the costal cartilages, while the line of the costo-chondral junction becomes a deep groove. The sides of the chest are flattened, and a transverse section would be almost triangular in shape. There are three modes of production of this very common deformity:

1. In rickety children it is favored by the softening of the bones and cartilages, which are thus of diminished resiliency, the actual exciting cause being often some form of respiratory obstruction,—*e.g.*, enlarged pharyngeal and faucial tonsils, bronchitis, nasal obstructions, etc. In ordinary breathing, on inspiration, air enters the chest freely to prevent the production of a vacuum, and at the end of the act the external atmospheric pressure is balanced by the pressure within. If an impediment to the free ingress of air exists, the external pressure during at least part of the act is in excess, and in young children, particularly rickety children, this is followed by the bending inward along the weakest part of the thorax (the costo-chondral line) and the relative projection of the sternum.

2. The lowest five costal cartilages form an especially weak portion of the chest-wall. They are the most distant from the fulcrum (the spine) on which the ribs move in respiration, and hence the expansive forces act with the greatest disadvantage of leverage (Humphry). At the same time the diaphragm, during its contraction, tends to draw them inward. If, however, its central arch cannot descend during inspiration on account of an engorged liver, enlarged abdominal lymphatics, persistent flatulence, etc. (as in a poorly nourished child), it becomes the fixed point, and the lateral walls are pulled in and the sternum correspondingly protruded.

3. Some cases of "pigeon-breast" are seen at or soon after birth in otherwise healthy children. It is probable that these are cases of arrest of development. The so-called "keeled chest" (in which the antero-posterior diameter is increased at the expense of the transverse diameter) is characteristic of the quadrupedal class of mammals, and is necessitated by, and correlated with, the backward and forward swing of the anterior limbs in walking.[1] In the fœtus the antero-posterior diameter is relatively greater than in the adult.

Attention has already been called (page 164) to the varying ratio between the antero-posterior and transverse diameters of the chest, the transverse diameter in the adult exceeding the anterior in the proportion of 2.5 to 1. If this change stops short of full completion, a greater or less degree of relative prominence of the sternum results.

The "bellows chest"[2] is found among mammals almost exclusively in the bats, the anthropoid apes, and man, that have in common simply the disuse of the anterior limbs as a means of support. In them the chief movements of these limbs tend to pull the sternum towards the vertebral column. The exaggeration of this type results in the so-called "flat chest," which is, however, within proper limits, the type of vigor, as it results from the full contraction of normal muscles.

Emphysema produces a rotund configuration of the chest-walls, affecting chiefly the upper portion, throwing out the ribs, effacing the intercostal spaces, and making the thorax "barrel-shaped."

Old age, owing to an increased bowing of the thoracic spine under the weight of the head and shoulders and to a slipping forward of the shoulder-girdle with its mass of muscles, often causes a depression of the sternum and its approximation to the spine,—a common form of flat chest.

[1] Woods Hutchinson: Journal of the American Medical Association, vol. xxix., 1897.
[2] Ibid.

The pulmonary capacity is but roughly indicated by the circumference of the chest, as the vertical diameter is also obviously an important determining factor. Chest measurements, to be of value, should therefore be supplemented by investigation into the amount of air which can be inhaled and exhaled. The resulting information is often of great value as a basis for prognosis and for advice as to exercise and hygiene, especially in persons with a predisposition to pulmonary disease.

In the infant the thorax is relatively smaller than in the adult. In the female the upper portion of the thorax is less compressed from before backward and is more capacious than in the male. The upper aperture is larger and the range of movement between the upper ribs and the sternum and vertebræ is greater. These circumstances account both for the fulness of the upper portion of the chest in the female and for the character of the respiratory movement, which is known as *thoracic*; while that of the male, in which the lower ribs and abdominal walls move more freely, is known as the *abdominal* type of respiration.

The **sternum** may be entirely wanting, or may be divided into two portions by a fissure down the middle, the result of developmental failure, which, when it exposes the thoracic cavity and the heart, is known as *ectopia cordis*.

Its subcutaneous position makes it the subject of slight but frequent traumatisms, which often serve to localize the bone lesions of syphilis, tuberculosis, and other infections; and this fact, in conjunction with its cancellous structure, accounts for the frequency with which it is the seat of gummatous periostitis and tuberculous caries. There are sometimes little circular defects in the body of the sternum, through which an abscess may pass from the mediastinum outward, or infections from without may find their way within the thorax. They are congenital defects due to a failure of the two halves of the body of the sternum to unite.

The seven depressions on each side of the sternum for the reception of the cartilages of the seven true ribs are so shaped that the upper and anterior edges of each notch are more prominent and larger than the lower and posterior edges. This accounts for the rarity of luxation forward of these cartilages and their ribs by the forces which so constantly pull the ribs upward and forward, as the action of the scaleni and intercostals in violent inspiratory efforts, that of the pectorals in swinging by the hands or on parallel bars, etc.

Backward dislocation at the chondro-sternal junction is even rarer; but this is because, owing to the elastic curves of the ribs, the sternum and the anterior extremities of the ribs move backward together on the application of direct force to the front of the chest.

As it is thus movable, and is supported on the ends of elastic levers or springs, the sternum is rarely fractured. When the fracture is the result of indirect violence, it is often associated with injuries to the spine, as the extreme extension or extreme flexion, which is the common cause of a sternal fracture, must necessarily put a severe strain on the thoracic spine.

In extension the sternum is fixed between the sterno-mastoids and sterno-hyoids and thyroids above and the recti and diaphragm below. In flexion the force may be transmitted through the chin. In either case the most common seat of fracture is at or about on a line with the second costal cartilage, because (*a*) the bone there is narrowest (Fig. 173), and (*b*) at that level lies the junction between the manubrium and body. As the various portions of the bone are not united until about twenty years of age, fracture is almost unknown before that time. Moreover, during that period the symphysis between the manubrium and the body is so shaped that, together with the natural curve forward of the bone, it increases the elasticity of the sternum and enables it to resist both direct violence and tensile strain.

The projection[1] at the union between the manubrium and body (*angulus Ludovici*) is sometimes exceptionally prominent, and when this is noticed for the first time after an accident or an illness, may give rise to the erroneous diagnosis of fracture or of bone disease. This angle is increased in phthisis, owing to the recession of the manubrium; it is increased in emphysema, as the second ribs carry forward the lower border of the manubrium.

The greater thickness and strength of the layer of fibrous tissue that covers

[1] Angulus sterni.

the posterior surface of the sternum, as compared with that on the anterior surface, account for the rarity with which effusions of blood or collections of purulent fluid find their way to the anterior mediastinum.

The **ribs**, in addition to the already described classification into *sternal, asternal*, and *floating*, are sometimes designated as *upper* and *lower*. It may be well to mention that the term "upper" includes the first six ribs, which have convex lower borders, give origin to the pectoralis major (an elevator of the ribs), and move upward in inspiration; while the term "lower" applies to the last six ribs, which have concave lower borders, give origin to the diaphragm (a depressor of the ribs), and move downward in inspiration.

The obliquity of the ribs adds greatly to their range of movement in respiration. The most oblique rib, the longest, and the most movable—the seventh—is a part of the wall of that portion of the thorax that contains the largest amount of pulmonary tissue. The most fixed and most nearly horizontal of the ribs (and the shortest of the sternal ribs)—the first—is a part of the wall where the least lung tissue is to be found. The ribs below the eighth have less and less relation to the lungs, and become both shorter and more horizontal. They have increased mobility as regards their anterior ends, but lessened rotation on a line drawn between their two extremities, the movement most important in respiration.

These facts have relation to the distribution of acute and chronic disease in the lungs: the acute affecting particularly the area of greatest movement and vascularity, the bases; the chronic, the area of lessened mobility and expansion, the apices.

The involuntary partial immobilization of the chest-wall after injury and in inflammatory affections of the pleura is of some diagnostic value, as is also the permanent restriction of its movements following the contraction of old adhesions, as after a pleurisy, or pleuro-pneumonia, or fibroid phthisis.

The obliquity of the ribs serves also the purpose of securing the necessary expansion of the chest with the least possible motion in the joints between the ribs and the spine and between the cartilages and the sternum. They are thus but little liable to strain, and, in spite of their unceasing movement during life, are very rarely the seat of either dislocation or disease.

At the articulation of the ribs with the spine the provision for preventing the ascent of the ribs during the action of the inspiratory muscles (similar to that at the costo-sternal junction) is seen in the fact that the articulating surface of the upper vertebra entering into the joint stands out more boldly than that of the lower one. The participation of the intervertebral disks in the costo-vertebral articulation gives greater safety to those joints and adds to the elasticity of the whole thorax by furnishing a resilient buffer which takes up and distributes forces directed against the chest-wall.

Variation in the development of the costal element of the seventh cervical vertebra (page 129) may result in the production of a cervical rib. This, growing beyond its ordinary limits, sometimes reaches half-way to the sternum, running parallel to the first rib, with which its anterior end is sometimes joined. Occasionally a process grows up from the first rib to meet it. This, or the cervical rib itself, may raise the subclavian artery and give rise to a mistaken diagnosis of aneurism, or may be thought to indicate chronic (tuberculous or syphilitic) infection of bone, and lead to unnecessary operation or treatment.

As a result of rickets, changes often take place at the chondro-costal junctions, causing *beaded ribs* when a few bones only are affected, or the "rickety rosary" when the enlargements are bilateral and numerous.

The ribs most frequently broken are the sixth, seventh, and eighth; the first and second are protected by the clavicle; the lower two by their small size and great mobility. The most common form of muscular action causing fracture is coughing; sneezing and lifting heavy weights have had the same effect. The lower ribs are most frequently broken in this way. When the first rib is broken, a characteristic symptom is said to be pain behind the upper part of the sternum on lifting with the hand on the injured side. This may be due to the fact that the first thoracic nerve lies for about two inches in contact with the under surface of the first

rib, and ends at or near the region mentioned, pain being often referred to the peripheral ends of sensory nerves.

In fractures by indirect violence (when the sternum and spine are forced together), the theoretical point of fracture would be at or about the summit of the arch; but practically it is often found very near the point at which the force is apt to be received,—*i.e.*, an inch or two outside of the sternal extremity.

Unless the force has been great, there is but little displacement in fracture of a rib, owing to the splinting of the bone between the two sets of intercostal muscles above and below it. Shortening is absent, unless an extensive crush of the whole side of the chest has occurred, because the two ends of the bone are fixed, and because of the unbroken bones above and below the fractured one. The complications are those obviously due to the proximity of the pleura and lung on the inner surface of the fracture, the common results of wounds of those structures being various degrees of hæmothorax, or pneumothorax, or sometimes (by valvular action) emphysema of the cellular tissue of the trunk (page 1865).

Broken ribs always unite with a considerable amount of ensheathing or provisional callus, due to the motion which to some degree must be present between the fragments during the process of union.

Rupture of an intercostal artery (unless associated with a wound of the pleura) is not usually a serious complication; but occasionally it is necessary to arrest hemorrhage from this vessel. It lies between the inner and outer intercostal muscles in the groove running along the lower part of the inner surface of each rib. The collateral branch runs near the upper surface of the ribs. Midway between the ribs is, therefore, the safest place to introduce a trocar or to make an incision in opening the chest. The intercostal spaces are wider in the antero-lateral parts of the chest than they are more posteriorly, especially in the neighborhood of the seventh rib; they are narrowest in close proximity to the sternum and spine. They can be widened by bending the body to the opposite side.

For paracentesis of the thorax the centre of the sixth or seventh space should be selected in the mid-axillary line. The lower spaces are in too close proximity to the diaphragm, especially on the right side. More anteriorly it is also in danger; farther posteriorly the intercostal artery (which runs more horizontally than the ribs) crosses the space obliquely, and behind the angles the ribs are covered by the thick muscles of the back.

The ribs are frequently subject to infectious disease. Syphilis and tuberculosis often produce periostitis or caries, and they are more often the seat of post-typhoidal osteitis than any other bones of the skeleton. This is due to their subcutaneous position exposing them to frequent traumatisms and to the similar effects produced by the numerous strains through muscular action in coughing and sneezing and in lifting or straining.

Pus is very apt to travel along the loose connective tissue between the two planes of intercostal muscles, and it is therefore unusual to find suppurative disease confined to one rib, or even to the immediate vicinity of its point of origin.

No instance of traumatic separation of the epiphysis of either the head or the tuberosity of a rib has been recorded.

The internal mammary artery runs from above downward beneath the cartilages about half an inch from the sternum.

Landmarks.—The oblique elevations formed by the ribs can usually be seen extending downward from the axillary region. The upper ribs are covered by the great pectoral, but beneath its lower border the ribs from the sixth to the tenth can often be seen. The lower border of the great pectoral follows the direction of the fifth costal cartilage.

The curved arch of the costal cartilages is frequently plainly visible, and is accentuated during forced expiration and when a superincumbent weight is held up by the trunk and arms. In short persons the arch is commonly flatter than in tall ones.

In counting the ribs it is well to begin with the second, which is easily identified by its relation to the ridge between the manubrium and body of the sternum.

The nipple is usually over the fourth intercostal space, somewhat less than 2.5

centimetres (one inch) external to the costo-chondral junction, or about ten centimetres (four inches) from the middle line. Its position is variable, and is much lower in fat persons, especially females. In emphysema the nipple may remain stationary, while the upper ribs ascend, and it may be opposite the fifth, sixth, seventh, or even the eighth rib. In phthisis with a shallow depressed chest it may be opposite the fourth rib. A line drawn horizontally from the nipple around the chest is on a level with the sixth intercostal space at the mid-axillary line.

A horizontal line around the trunk on the level of the angle of the scapula (the arms hanging down) would traverse the sternum between the fourth and fifth ribs, the fifth rib at the nipple line, and the ninth rib at the vertebral column (Treves).

The sternum is subcutaneous in the groove between the pectoral muscles. Near the upper third the ridge between the manubrium and body may be seen or felt. It is on a level with the second costal cartilage. This cartilage projects forward more than the others. As the origins of the pectoral muscles diverge the sternal groove becomes broader. It ends at the lower portion of the body of the sternum in a slight projection usually seen and easily felt. This marks the upper limit of the "infrasternal depression" (*epigastric fossa*, *scrobiculus cordis*), the floor of which is over the ensiform process, and which is bounded laterally by the seventh costal cartilages and inferiorly by the upper ends of the recti muscles. In many abdominal diseases, and sometimes after laparotomies, the obliteration of this depression (by the occurrence of tympany) is an important clinical symptom.

When the arm is raised, the highest visible digitation of the serratus corresponds to the fifth rib; the largest is that attached to the sixth rib.

During expiration the upper end of the sternum is on a level with the second dorsal intervertebral disk; the line between the manubrium and body is on a level with the fifth thoracic vertebra; the junction of the sternal body and the ensiform process is opposite the lower part of the ninth thoracic vertebra.

The eleventh and twelfth ribs can be felt as blunt bony projections directed downward and outward just outside the erector spinæ muscles.

(The relations of the various thoracic viscera to the chest-wall will be considered in connection with the anatomy of the former.)

THE SKULL.

THE head consists of the cranium and the face. The former is the brain-case; the latter is chiefly concerned in forming the jaws. The head also contains the terminal organs of four special senses. That of hearing is entirely inside one of the cranial bones, while the organs of sight and of smell lie in cavities formed partly by cranial and partly by facial bones. The special organ of taste, a part of the surface of the tongue, is in the mouth, bounded wholly by facial bones. Thus, while the cranial bones have a share in forming the face, no facial bone has any part in forming the brain-case. The latter is an egg-shaped cavity which communicates by a large opening—the foramen magnum—with the spinal canal, through which the spinal cord passes down from the brain. The brain-case has many smaller openings in the base, through which nerves escape both to the face and to a large part of the body and blood-vessels pass for the nutrition of the brain and its membranes and the walls of the skull.

As the bones of the head can be separated in a young subject, it is customary to describe every bone by itself. It is too often forgotten that this knowledge is merely a means to an end,—namely, the understanding of the skull as a whole. In the following account this end is kept constantly in view.

THE CRANIUM.

The cranial cavity is formed by eight bones: the *occipital*, the *sphenoid*, the two *temporals*, the *ethmoid*, the *frontal*, and the two *parietals*. The cranium consists of the vault and the base. The **vault** is formed by the *parietals*, the greater part of the *frontal*, and a part of the *sphenoid*, of the *temporals*, and of the *occipital*.

The **base** of the cranium is divided into three fossæ extending across the skull. The *posterior fossa* is the lowest; it opens by the foramen magnum into the spinal canal, and contains the cerebellum, the medulla, and the pons. The *middle* one is narrow at the centre and expands laterally into the temporal regions. The *anterior* is the highest, lying above the orbits and the nose. The anterior fossa transmits the olfactory nerves, the middle the optic, the posterior the auditory and the glosso-pharyngeal, the nerve of taste.

THE OCCIPITAL BONE.

The occipital bone[1] is divided for description into an anterior part, the *basilar;* two lateral ones, the *condylar;* and a posterior one, the *tabular* or *squamous portion*. These correspond to the *basi-occipital*, the *exoccipital*, and the *supra-occipital* of comparative anatomy. They all develop from separate centres and bound the *foramen magnum*,[2] a nearly circular opening, transmitting the spinal cord with its enveloping membranes. The spinal accessory nerves and the vertebral arteries ascend within the latter from the cavity of the spine to that of the cranium.

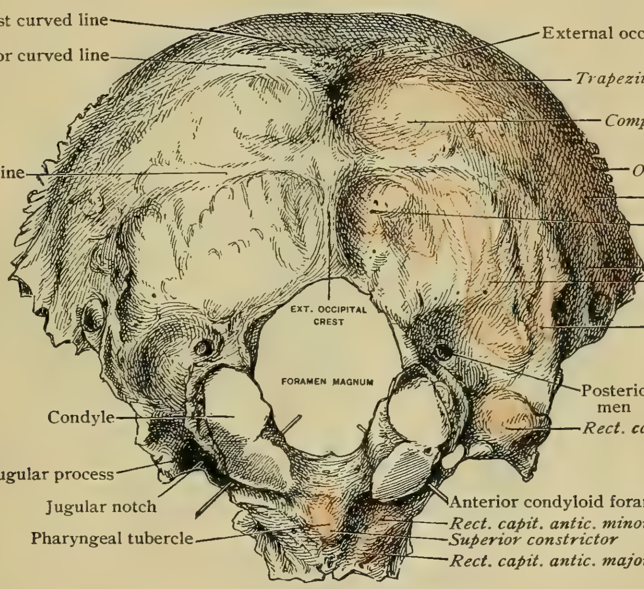
The basilar portion[3] bounding the foramen magnum in front is originally rough anteriorly, but shortly after puberty it coossifies with the body of the sphenoid. Its superior surface is smooth and concave and supports the medulla oblongata. Just internal to the edges is a very shallow groove for the inferior petrosal sinus. The inferior surface is smooth for about one centimetre in front of the foramen magnum, and rough in front of this for the rectus capitis anticus major and minor. In the middle line at the junction of the rough and smooth surfaces is the *pharyngeal tubercle*,[4] Very rarely this aspect presents a depression, the *pharyngeal fossa*. Sometimes there is a facet near the edge of the foramen for the anterior arch of the atlas. Also, there may be a tubercle on the posterior part of the basilar portion against which the odontoid process may rest, called the *third condyle*. Laterally, the basilar portion

[1] Os occipitale. [2] Foramen occipitale magnum. [3] Pars basilaris. [4] Tuberculum pharyngeum.

is separated by a suture, the *petro-occipital*, containing cartilage, from the petrous portion of the temporal.

Each **condylar portion** [1] (*exoccipital*) presents on the inferior surface an oval articular swelling, the *condyle*, which rests in the hollow on the atlas. They are placed on each side of the front half of the foramen magnum. The hind ends reach almost precisely to the middle of the aperture, and anteriorly they extend to the line of the anterior border, their long axes converging in front. The articular surface, which is convex in the line of the long axis, faces downward and outward. The curve it presents varies greatly. In some cases it is nearly regular, in others the front and back halves almost meet at an angle. There is usually a constriction of the articular surface at the middle, where it may be crossed by a groove or a ridge. On the thick inner border of each condyle is a *tubercle* for the odontoid ligament. Behind the condyle is a *fossa*, into which usually opens the inconstant *posterior condyloid foramen*,[2] transmitting a vein. In front of the base of the condyle at its outer border is the constant *anterior condyloid foramen*,[3] the termination of a canal, from five to ten millimetres long, which pierces the bone above the condyle and transmits the hypo-

FIG. 192.



Occipital bone, external surface, from below.

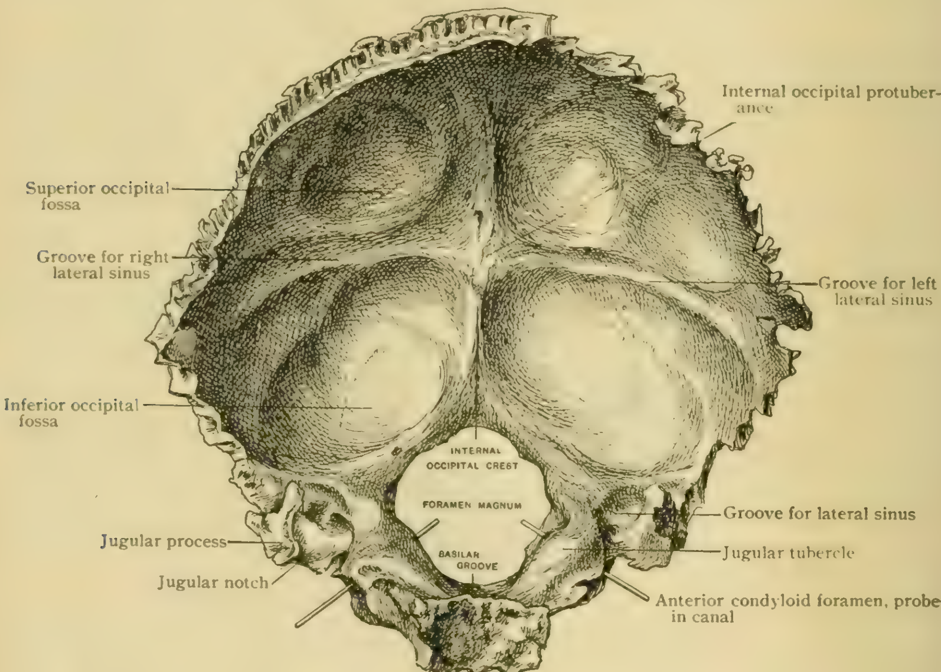
glossal nerve and, usually, a branch from the ascending pharyngeal artery and vein or veins. It is sometimes divided into two. The bone projects outward from the condyle as the *jugular process*,[4] which is enlarged at its outer end where it coössifies with the petrous portion of the temporal. This enlargement, moreover, extends downward as the *paroccipital process*, which shows its greatest development in odd-toed ungulates. In man it is usually very small, but it may be large and, very rarely, join the atlas. The concave front of the jugular process and the bone extending forward on its inner side form the *jugular notch*,[5] which bounds the *posterior lacerated foramen* [6] behind and internally. This is completed by the temporal bone. A very small point, the *anterior jugular process*, marks the front of the foramen. A little behind this a larger though very delicate spine, the *intrajugular process*, reaches across, marking off a small anterior part of the jugular foramen for the passage of the ninth, tenth, and eleventh nerves from the larger one behind for the lateral sinus. Sometimes the front of the jugular process is a smooth surface bounded below by a ridge to which is attached the rectus capitis lateralis, and above by a short border marking off a fossa on the upper surface of the bone ; occasionally

[1] **Pars lateralis.** [2] **Canalis condyloideus.** [3] **Canalis hypoglossi.** [4] **Processus jugularis.** [5] **Incisura jugularis.** [6] **Foramen jugulare.**

the latter ridge is wanting, the groove of the lateral sinus curving over the jugular process. The upper surface of the lateral portion of the process shows on its inner side the entrance of the anterior condyloid foramen, which is really a short canal. Above and anterior to this is a slight swelling, the *jugular tubercle*. The upper surface of the jugular process is marked by the termination of the groove of the *lateral sinus*, which curves round an upward projection of the process. In some cases, as just mentioned, the groove is depressed into a deep hollow. The inner opening of the posterior condyloid foramen, when present, is connected with the lateral sinus.

The **squamous portion** [1] forms the lower and back part of the skull. Below it contributes the posterior boundary of the foramen magnum and joins the exoccipitals. The lateral borders meet above at a sharp angle. These borders may be subdivided into a *lower part*, which ascends nearly vertically in articulation with the mastoid part of the temporal, and into a *higher part*, very serrated and joining the parietal. A slight angle lies on either side at the junction of these two divisions.

FIG. 193.



Occipital bone, internal surface, from before.

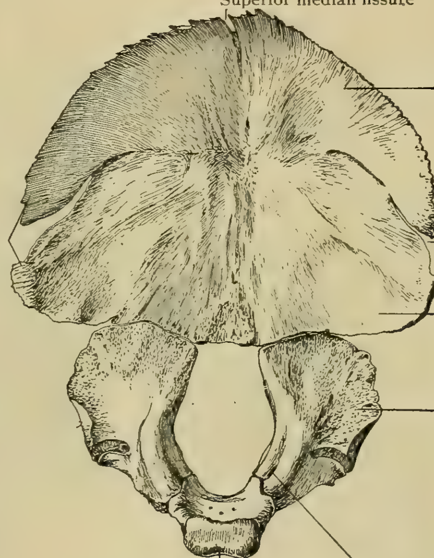
The **posterior surface** is marked by a prominence, somewhat below the middle, the *external occipital protuberance*,[2] to which is attached the ligamentum nuchæ. This tuberosity varies greatly in development. From it the *superior curved line*[3] extends laterally to the above-mentioned angle. To this line are attached a series of muscles which form the contour of the back of the neck, chiefly the trapezius and part of the sterno-cleido-mastoid. A short and varying distance above the superior ridge is often seen the so-called *highest curved line*.[4] It is usually very faint, and may curve down to the external occipital protuberance, or pass above it. The epicranial aponeurosis and part of the occipitalis spring from this line. The surface of the bone above the level of the protuberance is smooth; below it is rather rough and irregular. The *torus occipitalis transversus* is an occasional prominence involving the protuberance and extending laterally along the superior curved line. It sometimes involves the space between that line and the highest one. The upper border of the swelling may have a median concavity. In the mid-line a slight ridge,

[1] Squamosa occipitalis. [2] Protuberantia occipitalis externa. [3] Linea nuchae superior. [4] Linea nuchae suprema.

the *external occipital crest*,[1] runs from the protuberance to the foramen magnum. Above the middle of this crest the *inferior curved line*[2] leaves it to extend outward and downward to the border of the bone. The inner part of this line is rough, the outer indistinct. Below this line there is usually a depression on either side of the crest.

The **internal surface** of the squamous portion is divided into four depressions or *fossæ*; the upper two lodge the occipital lobes of the cerebrum and the lower two the lateral lobes of the cerebellum. Below the middle is the *internal occipital protuberance*,[3] approximately opposite to the outer. A ridge runs from the apex of the bone to the protuberance, and is continued as the *internal occipital crest*[4] to the foramen magnum. Very often the second part of this ridge divides shortly after its origin, so as to enclose a depression, the *vermian fossa*, so called because it is below the middle lobe, or vermis, of the cerebellum. A ridge runs transversely from the protuberance to the lateral angle of the bone. The superior vertical ridge may be grooved for the superior longitudinal sinus and the transverse ridge for the lateral sinus. More frequently the longitudinal sinus lies to one side of the vertical ridge and is continued into one of the lateral ones, much larger than its fellow, and usually the right, which lies above the transverse ridge, and shows in the bone no communication with the smaller, which lies in or above the other ridge. There are many variations in this arrangement, of which the rarest is a symmetrical course and division of the superior groove. A single or a bifurcated groove is sometimes found on the internal crest.

FIG. 194.



Occipital bone at birth, from before.

Development.—Four centres appear in the cartilage around the foramen magnum about the eighth week of fœtal life: one for the *basilar*, one for each *exoccipital*, and one (or more probably a pair that speedily fuse) for the lower part of the squamous portion, the *supra-occipital*. A week or so later two nuclei appear in the membrane above the latter, from which a strip of bone develops which soon joins it. From this upper ossification, the *superior occipital*, is developed all the upper part of the squamous portion, including the external occipital protuberance and the superior curved line.[5] Occasionally still another nucleus appears on each side, anterior and external to the preceding, which probably accounts for certain separate ossifications often found in the lambdoidal suture. The squamous part shows a median cleft above, which quickly disappears, two lateral ones between the ossifications, which persist till birth, and a notch at the posterior border of the foramen magnum. The squamous portion joins the exoccipitals in the course of the second or third year. The latter begin to unite with the basilar a year or so later. None of these sutures, especially the latter, is completely closed before the seventh year, or even later. The front parts of the condyles are formed from the basilar, which joins the exoccipitals at the anterior condyloid foramina. Separate ossifications, large *Wormian bones*,[6] are found in the suture between the squamous portion and the parietals. Sometimes there is a large median triangular one which is interpreted as the result of a want of union of the usual superior centre of the squamous portion, and said to

[5] Consult Stieda: Anatomische Hefte, iv., 1892, and Debièrre: Journ. de l'Anat. et de la Phys., 1895.

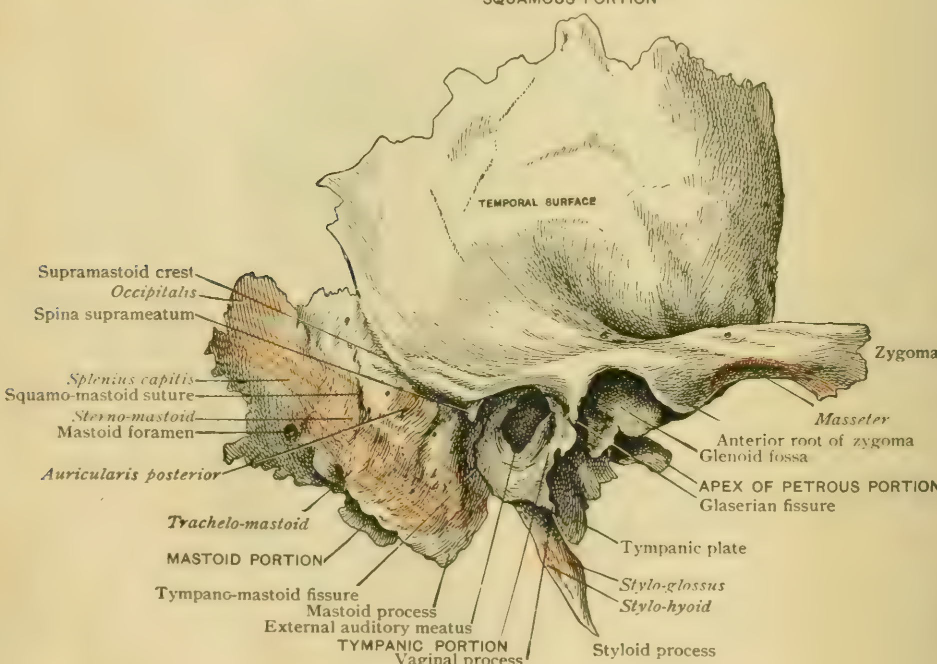
[1] Linia nuchae mediana. [2] L. nuchae inferior. [3] Protub. occip. interna. [4] Crista occipitalis interna. [6] Ossa suturarum.

be the homologue of the *interparietal bone*. This interpretation is inconsistent with the history of ossification. Kerkring has described an occasional triangular minute piece of bone which appears during the fifth month in the notch at the back of the foramen magnum, and is fused before birth. We have specimens which imply that it is, or may be, originally double. Improved methods of investigation will probably show that this bone is not uncommon. The cerebral side of the basilar is fused with the sphenoid by seventeen ; the lower side unites later, probably before twenty.

THE TEMPORAL BONE.

The plan of the organ of hearing must be known to understand the temporal bone.[1] The external ear, besides the auricle, consists of a cartilaginous and bony tube, the *external auditory meatus*,[2] leading to the membrane of the tympanum which closes it. The middle ear, the *cavity of the tympanum*, is a space internal to the

FIG. 195.



Right temporal bone, external aspect.

membrane, opening through the *Eustachian tube* into the throat, and communicating behind with cavities in the bone. It is lined with mucous membrane and is crossed by a chain of small bones, the *ear ossicles*, the embryological importance of which is explained elsewhere. The internal ear is a complicated system of cavities in the substance of the bone containing the organ of hearing connected with the brain by the auditory nerve, which leaves the bone through a canal, the *internal auditory meatus*.

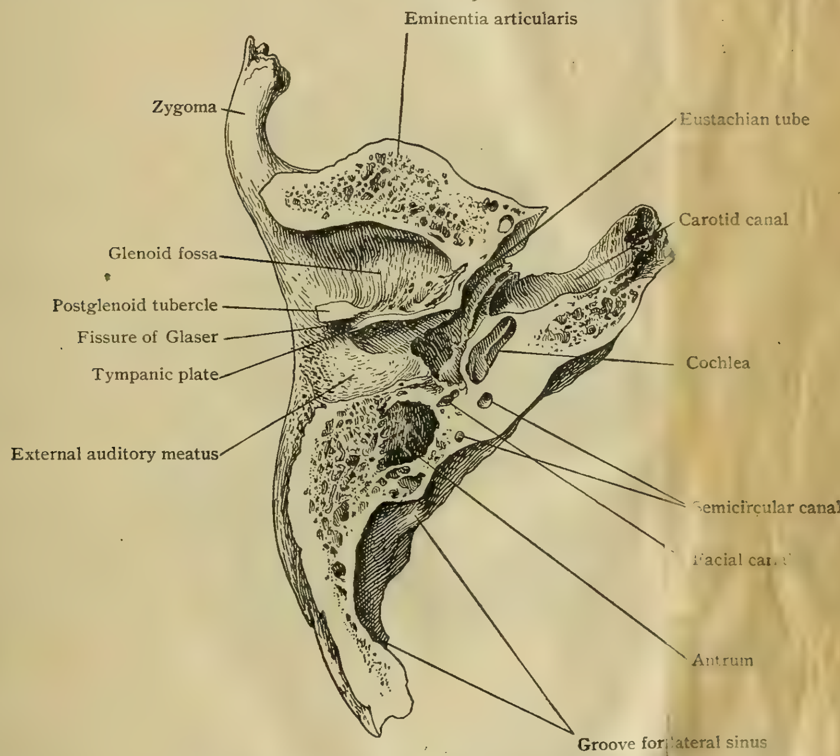
Development shows that the bone consists of the following three parts. (1) The *petro-mastoid*, the *petrous part* of which is first found surrounding the special apparatus of the organ of hearing, constituting the internal ear, while the *mastoid process* is a much later outgrowth. (2) The *tympanic portion*, which at birth is a ring, incomplete above, encloses the membrane of the tympanum as a frame holds a glass. This ring grows out later into a cylinder, still open above, which forms the external auditory meatus. Not all its growth, however, is outward, since a part

[1] Os temporale. [2] Meatus acusticus externus

expands forward and deeper than the original ring, making the front part of the *tympanic plate*, bounding the cavity of the tympanum and the Eustachian tube externally. The tympanic cavity, or the middle ear, lies between the petro-mastoid and the tympanic portion, the roof and floor being developed from the former. (3) The *squamous portion* is external and above. It forms a part of the side of the skull, the roof of the external meatus where the tympanic portion is deficient, the articulating surface for the jaw, and a part of the mastoid process. There is also the long, slender *styloid process*, which is a part of the hyoid bar of the second visceral arch of the embryo. It begins as an ossification of a distinct piece of cartilage, but joins the petro-mastoid. The following description is that of the adult bone.

The Squamous Portion.[1]—Most of this is a thin vertical layer forming part of the wall of the skull, joined below by a horizontal one which forms a small part of the base of the skull, the articulating surface for the jaw, and the roof of the external

FIG. 196.



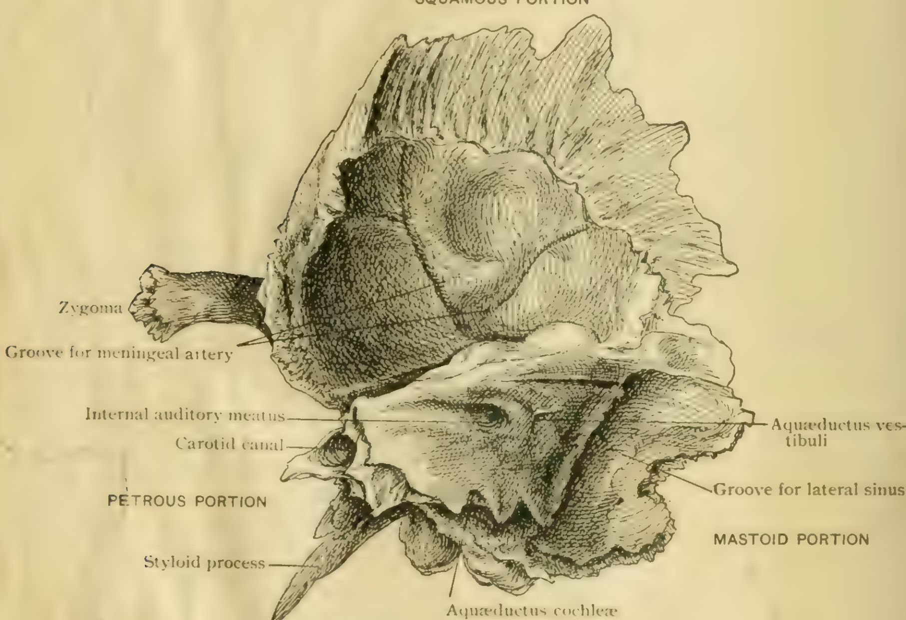
Horizontal section through right temporal bone, seen from below.

auditory meatus. The edge of the vertical part is convex except below. The upper and posterior borders overlap the parietal bone by a broad bevelled surface. The anterior border joins the great wing of the sphenoid, overlapping above and overlapped below, where it passes into the horizontal part. The posterior angle of the vertical portion sends downward the *postauditory process*, from which the upper part of the mastoid, including some of the mastoid cells, is developed. The *squamo-mastoid suture*, separating this from the mastoid portion, is usually lost in the second year. When it persists, it shows that the anterior portion of the mastoid down to the lower border of the external meatus, or even lower, is formed from the squamosal. Its surface is smoother than that of the mastoid proper. A small, particularly smooth, but inconstant patch situated on the level of the upper [illegible] of the [illegible], one centimetre or more behind it, marks the position of the [illegible]. The thickness of the bone at this place, which is that of note-paper in the [illegible] reaches

[1] Pars squamosa.

six millimetres in the adult. A small, sharp prominence, the *spina suprameatum*, is found just behind the upper part of the meatus. It is an important landmark in the surgery of the region. Just posterior to it is usually a minute venous foramen. The inner side of the squamous portion, besides the large bevelled articular surface, presents a smooth one, forming part of the wall and floor of the cranial cavity. This is separated from the petrous portion by the *petro-squamous suture*, which is closed early. Two *grooves* for branches of the middle meningeal artery diverge from its lower border, one running upward and the other backward. The front of the horizontal part forming the floor is rough and thick, joining the great wing of the sphenoid. The *zygomatic process*[1] projects forward from the outer surface of the squamosal to complete the *zygomatic arch* with the malar, which it joins by a serrated end. The free part has an external and an internal surface, a rounded border below and a sharp edge above. The latter, which receives the insertion of the temporal fascia, can be followed back to the origin of the process. The zygoma has two roots. The *posterior root* passes directly backward above the auditory

FIG. 197.



Right temporal bone, internal aspect.

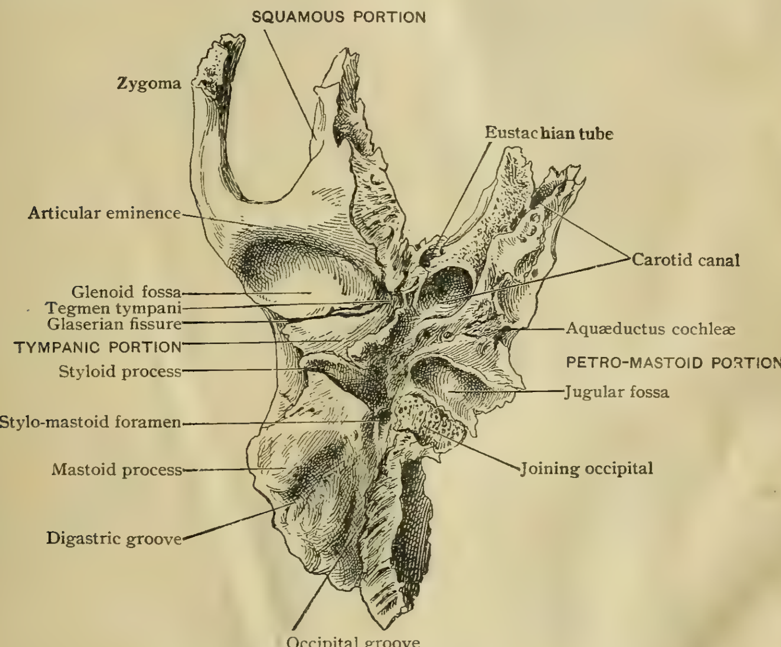
meatus, crosses the squamous portion above the postauditory process, and, curving slightly upward, is lost at the notch between the squamous and mastoid portions. Its hind part is the *supramastoid crest*, which joins the inferior temporal ridge on the parietal. The *anterior root* bends sharply inward. It is grooved above for the passage of the fibres of the temporal muscle. Its lower surface forms a semi-cylindrical transverse elevation, the *eminentia articularis*,[2] the front part of the articular cavity of the lower jaw. Near its outer end is a *tubercle* for the external lateral ligament. Just in front of the auditory meatus, on the under side of the bone, is the smaller *postglenoid tubercle*, sometimes described as a third root. The *glenoid fossa*[3] is a deep hollow on the under side of the squamous portion, with its greatest diameter nearly transverse, but passing somewhat forward and outward, bounded externally by the posterior root of the zygoma; behind, by the *fissure of Glaser*,[4] which separates it from the tympanic portion; and extends forward and inward to meet the inner end of the eminentia articularis. Both glenoid fossa and articular eminence are covered with cartilage. The bone separating the glenoid fossa from

[1] Processus zygomaticus. [2] Tuberculum articulare. [3] Fossa mandibularis. [4] Fissura petrotympanica.

the interior of the cranium is very thin. Behind the glenoid fossa the horizontal part of the squamosal forms the roof of the external auditory meatus.

The Tympanic Portion.[1]—The tympanic portion of the temporal bone appears as a trumpet-shaped layer of bone, forming all but the roof of the external auditory meatus. Its edge is thin in front, thick below, and very thin behind, where it curls up before the mastoid to meet the postauricular process of the squamosal. It is separated from the mastoid by the minute *tympano-mastoid fissure*. The anterior part of the tympanic portion, called the *tympanic plate*, runs obliquely forward, concealing the petrosal. It is separated from the glenoid fossa and from the thick anterior edge of the squamosal by the *fissure of Glaser*, which opens into the tympanic cavity. The outer end of the fissure is closed ; the inner part is double, since a thin piece of the petrous, the *tegmen tympani*, bends down between the squamous and tympanic portions. The lower edge of the tympanic plate ends free. A part covering the base of the styloid process is the *vaginal process*,[2] which sometimes splits to enclose it.

FIG. 198.



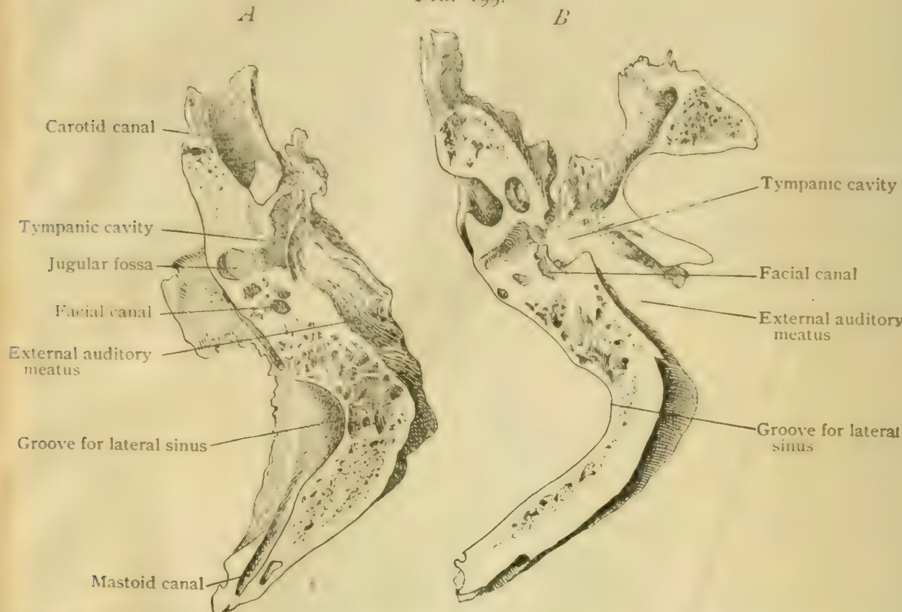
Right temporal bone from below.

The Petro-Mastoid Portion.[3]—This part of the temporal bone may for convenience of description be subdivided into the *mastoid* and the *petrous*. The **mastoid subdivision** forms a part of the wall of the skull behind the tympanic. It is prolonged downward into a nipple-shaped process, the outside of which is rough and slightly prominent. On its lower surface, under cover of the apex, is the *digastric groove*[4] for the origin of the posterior belly of the digastric muscle. Just internal to this, at the very edge of the bone, is the much-smaller *occipital groove* for the occipital artery. The ridge between the two may be developed into a *para-mastoid process*. The greater part of the internal surface is occupied by a broad and deep *groove*,[5] running obliquely downward, forward, and inward for the lateral sinus on its way to the jugular foramen. The direction of this groove is very uncertain. Sometimes it descends gradually ; at others it turns far forward and descends nearly vertically. In the latter case it approaches closer than otherwise to the outer wall of the skull, but the distance in all cases is very variable (Figs. 199, 200). It may be only a few millimetres. As it descends it reaches the inner side of the antrum and the mastoid cells. It is separated from the antrum by a plate some six

[1] Pars tympanica. [2] Vagina processus styloidei. [3] Pars petrosa et mastoidea. [4] Incisura mastoidea. [5] Sulcus sigmoideus.

millimetres thick in early childhood, and from the antrum or upper mastoid cells by a very thin one in adult life.[1] Behind the groove a small, smooth surface forms a part of the cerebellar fossa.

FIG. 199.



Horizontal sections through a right temporal bone with slight development of the mastoid cells. *A*, just above the floor of the external auditory meatus; *B*, near the roof of the same canal.

FIG. 200.

Similar sections of a right temporal bone with considerable development of the mastoid cells and consequent removal of the lateral sinus from the surface.

A small canal, the *mastoid foramen*,[2] transmitting a vein, runs from the sinus to the outside of the bone, which it sometimes reaches as far back as the suture between

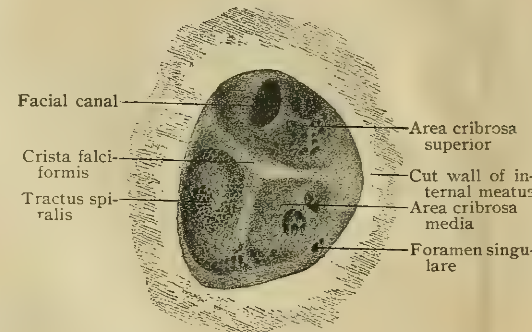
[1] Clarke: Journal of Anatomy and Physiology, vol. xxvii, 1893.

[2] Foramen mastoideum.

the temporal and the occipital. The interior of the mastoid process contains spaces, the *mastoid cells*, to be described later. The size and shape of the mastoid process are very variable. The rough upper border of the mastoid subdivision forms an entering angle with the squamosal, into which fits a sharp point from the lower border of the parietal, which rests on it above. Behind and below the mastoid joins the occipital bone.

The **petrous subdivision** is an elongated pyramid running forward and inward, presenting four surfaces (besides the base covered by the mastoid), four borders, and an apex. The surfaces are the superior, posterior, inferior, and anterior.

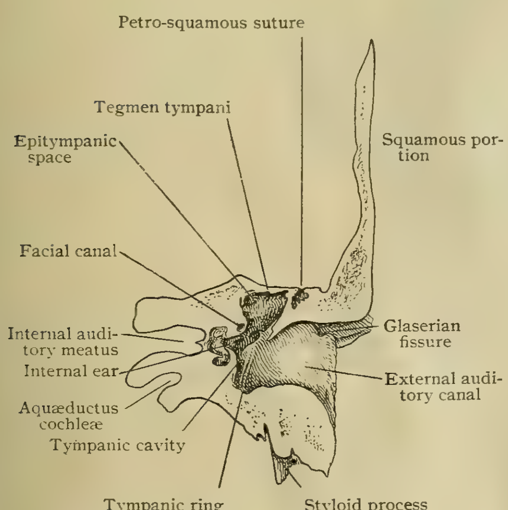
FIG. 201.



Bottom of right internal auditory meatus. × 5.

The **superior surface** slants forward and downward in the floor of the middle cerebral fossa. It has the following features. Above the apex there is a *depression*[1] for the Gasserian ganglion. Just external to this the bone is excessively thin and often deficient, so as to leave the end of the carotid canal uncovered. Behind the middle of the pyramid is an *elevation*, nearly at right angles to its long axis, caused by the superior semicircular canal. External to this the surface is made of a very thin plate of bone, the *tegmen tympani*, which, extending outward from the petrous, forms the roof of the tympanum and of its continuation, the Eustachian tube. Externally, this plate bends down into the Glaserian fissure, so that its edge may appear between the squamosal and tympanic portions (Fig. 198). At the inner border of the tegmen tympani near its front is a groove leading to a little rent in the bone, the *hiatus Fallopii*,[2] through which passes the great superficial petrosal nerve. A minut opening, more external, transmit the smaller superficial petrosal nerve. In youth the outer side of the tegmen is bounded by the *petro-squamous suture*.

FIG. 202.



Frontal section through temporal bone, showing the cavities of the outer, middle, and inner ear and the four sides of the petrous.

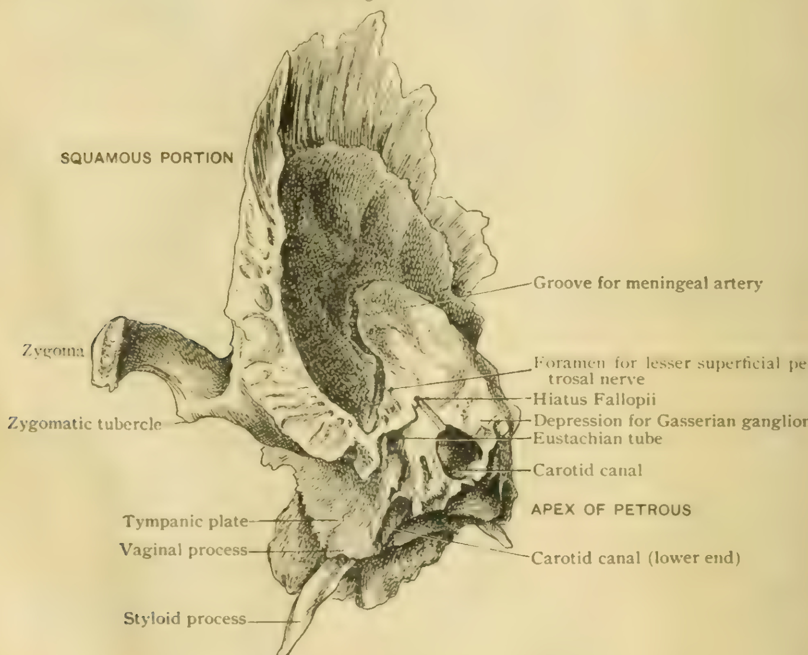
The **posterior surface** forms a part of the posterior cranial fossa. The chief feature is the *internal auditory meatus*,[3] a nearly round canal with a slight groove leading to it from the front. Its shorter posterior wall is about five millimetres long. The canal is closed by a plate of bone, the *lamina cribrosa* (Fig. 201), which is divided by the *falciform crest* into a smaller fossa above and a larger one below. The former has an opening by which the facial nerve enters its canal, the *aqueduct of Fallopius*. Branches of the auditory nerve pass through minute openings in both fossæ. About one centimetre behind the meatus is a little cleft, the *aquæductus vestibuli*,[4] entering the bone obliquely from below. Higher and nearer to the meatus is a minute depression, the remnant of the *floccular fossa*,[5] which is large in some animals and in the infant. It receives a fold of the dura.

The **inferior surface** of the petrous presents in front a large rough surface for

[1] Impressio tegmenti. [2] Hiatus canalis facialis. [3] Meatus acusticus internus. [4] Apertura externa aquaeductus vestibuli. [5] Fossa subarcuata.

the origin of the levator palati and tensor tympani muscles. External to the back of this is the round orifice of the *carotid canal*[1]; back of this, and more internal, is the *jugular fossa.* This presents two extreme types, entirely different, with intermediate forms. It may be a large thimble-shaped hollow, the edge of which bounds the venous part of the jugular foramen internally, forming a large reservoir for the blood of the lateral sinus as it leaves the skull. On the other hand, it may be a [illegible] flat surface. A minute, but very constant, *foramen* in the ridge between it and the carotid canal transmits the tympanic branch of the glosso-pharyngeal nerve. A minute *foramen,* usually found in the jugular fossa, transmits the auricular branch of the vagus. The *aquæductus cochleæ* ends at a small triangular opening[2] in front of the jugular fossa, close to the inner edge. Behind the fossa is a small surface where the temporal bone is united to the occipital, first by cartilage and then by bone. The *stylo-mastoid foramen*, the orifice of the facial canal for the facial nerve, is near the outer edge of this surface. The stylo-mastoid branch of the posterior auricular artery enters it.

FIG. 203.



Right temporal bone from before.

The **anterior surface** of the petrous is nearly all hidden by the tympanic plate. It forms the inner wall of the cavity of the tympanum and of the bony part of the Eustachian tube, which leaves the bone in the entering angle between this surface of the petrous and the tympanic. The features of this surface are treated in the section on the ear. The *processus cochleariformis*,[3] attached like a shelf to this outer wall, divides the canal for the tensor tympani muscle from the Eustachian tube below it. The front of this plate can be seen at the entering angle, where the bony tube ends. The small portion of the outer surface of the petrous which is visible is in front of this point, and rests against the inner edge of the great wing of the sphenoid.

The **superior internal border** of the petrous is a prominent ridge in the base of the skull, separating the middle and the posterior fossæ. The tentorium is attached to it. The superior petrosal sinus runs along it in a shallow *groove* within the attached border of the tentorium. Near the front a groove by which the fifth nerve reaches the Gasserian ganglion crosses this border.

The **inferior internal border** articulates anteriorly with the basilar process of

[1] Canalis caroticus. [2] Apertura externa aquaeductus cochleae. [3] Septum canalis musculotubarii.

the occipital bone, and is separated posteriorly from the occipital by the *jugular foramen*. A little spine on the edge of the thimble-shaped fossa, or on the plane surface that may take its place, the *intrajugular process*, joins the corresponding process of the occipital either directly or by ligament, so as to divide the foramen into two parts, the posterior for the vein, the anterior for nerves. In front of the foramen a small groove on the cerebral edge of this border marks the position of the inferior petrosal sinus.

The **superior** and the **inferior external borders** are concealed by the other elements of the temporal, except near the front, where they bound the surface which touches the sphenoid.

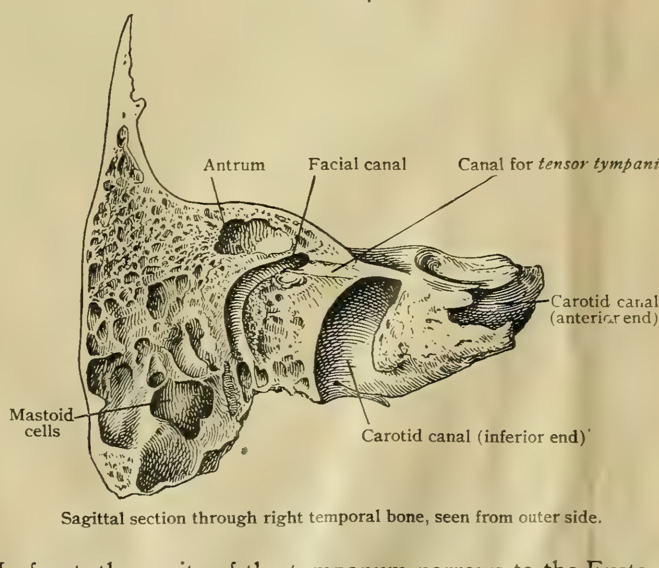
The **apex** of the petrous is mostly occupied by the opening of the carotid canal.

The **styloid process** is a part of the hyoid bar (from the second branchial arch), which joins the temporal under cover of the vaginal process. It is thick at its origin, but presently becomes thinner and ends in a sharp point. It is usually about an inch long, but varies greatly. It runs downward, forward, and inward, and is continued as the stylo-hyoid ligament to the lesser horn of the hyoid. Three muscles, the stylo-glossus, stylo-hyoid, and stylo-pharyngeus, diverge from it to the tongue, the hyoid bone, and the pharynx. An ill-defined process of the cervical fascia, the stylo-maxillary ligament, passes from it to the back of the ramus of the lower jaw.

CAVITIES AND PASSAGES WITHIN THE TEMPORAL BONE.

The Cavity of the Tympanum.[1]—The tympanic cavity is a narrow cleft about five millimetres broad at the top, narrowing to a mere line below. It measures about fifteen millimetres vertically and from before backward. It is bounded internally by the petrous; above by a projection from it, the *tegmen tympani;* below by the jugular fossa, or, if this be very small, by the bone external to it; externally by the tympanic portion of the bone and the membrane, except at the top, where the squamosal is external to it. The part above the level of the membrane is the *supratympanic space*, the *attic*, or the *epitympanum*. This is separated from the cranial cavity by a very thin plate, which is sometimes imperfect. In front, the cavity of the tympanum narrows to the Eustachian tube. It opens behind through the antrum, which serves as a vestibule, into the mastoid cells. The *antrum* is a cavity of irregular size and shape, compressed somewhat from side to side, with an antero-posterior diameter of from ten to fifteen millimetres, situated behind the epitympanum in the backward projection of the squamosal, which forms the superficial part of what appears to be the mastoid, and contains some of the so-called *mastoid cells*. The communication with the tympanum is a narrow one, and a certain number of cells open into the latter independently.

FIG. 204.



Sagittal section through right temporal bone, seen from outer side.

The antrum and the cells nearest it are lined with mucous membrane continued from the middle ear. The inside of the mastoid varies greatly. Sometimes it con-

[1] The detailed description of this space is given in connection with the ear.

tains large pneumatic cavities, sometimes diploë instead of air-cells, and, again, it may be almost solid; the latter condition is, however, probably always pathological. According to Zuckerkandl's[1] investigations of 250 temporal bones, the mastoid is entirely pneumatic in 36.8 per cent. and wholly diploetic in 20 per cent. The remaining 43.2 per cent. were mixed, the diploë being at the point of the mastoid and the cells above. Neither size nor shape indicates its internal structure. The relation of the cells to the lateral sinus has been already mentioned.

The Facial Canal.—The course of the canal[2] for the facial nerve is important. It runs outward from the superior fossa of the internal auditory meatus for some three millimetres, until joined by the canal from the hiatus Fallopii. It then makes a sharp turn (the *genu*) backward, passing internal to the attic of the tympanum just below the external semicircular canal, which almost always projects a little farther outward. It then curves backward to descend to the stylo-mastoid foramen, passing just above the fenestra ovalis. The descending portion is rarely strictly vertical. Below the genu the facial canal may make a bend either outward or inward, but its general line of descent usually inclines outward, sometimes very strongly. Rarely the descent is tortuous. The lower part may incline forward. The genu is opposite a point on the surface above the external meatus, and the subsequent course of the canal can be indicated in general by a line following the posterior border of the auditory opening. An instrument introduced *straight* into the front of the mastoid will pass behind the facial canal.[3] The diameter of the latter is about one and one-half millimetres. Just before its lower end a very minute canal, transmitting the chorda tympani nerve, runs upward and forward from it to the cavity of the tympanum. From the front of the cavity this nerve escapes by the minute *canal of Huguier*, which opens near the inner end of the fissure of Glaser, passing between the tympanic plate and the tegmen tympani. The facial canal has several other minute openings. There are also minute canals for *Jacobson's nerve* from the glosso-pharyngeal, leading to the tympanum, and for *Arnold's* branch of the vagus, which enters the jugular fossa and leaves by the fissure between the mastoid and tympanic portions.

The **carotid canal**[4] is close to the front of the tympanum and just before the cochlea of the internal ear. The internal auditory meatus is almost behind the canal, and the Eustachian tube lies to the outer side of its horizontal portion.

The temporal bone is porous in structure, except about the internal ear, where it is very dense. A transverse section, either vertical or horizontal, through the external and internal meatus (the middle and internal ears) shows how nearly the entire bone is pierced (Fig. 202). The carotid canal and the jugular fossa, when deep, are further sources of weakness. The fossa sometimes opens into the middle ear by a small rent.

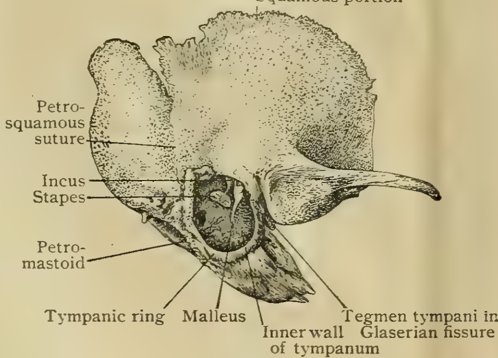
Articulations.—The temporal bone joins the occipital by the petro-mastoid portion. These two bones form the entire posterior fossa of the skull, except at the extreme front, in the middle, where it extends along the back of the sphenoid, and at the side, where a small portion of the lateral sinus is made by the posterior inferior angle of the parietal. This latter bone articulates with the squamous and the top of the mastoid. The great wing of the sphenoid fits into the angle between the squamous and petrous portions, articulating at the side of the skull with the front of the former. These two bones—the sphenoid and the temporal—form the entire middle fossa. The malar bone joins the zygoma, completing the arch. The lower jaw articulates with the glenoid fossa by a true joint.

Development.—The *squamous portion* is ossified in membrane from one centre, appearing near the end of the second month of fœtal life. In the course of the third month a centre appears in the lower part of the future tympanic ring. The ossification of the *petro-mastoid portion* comes from several nuclei, the number of which probably varies. The process begins towards the end of the fifth month about the membranous labyrinth. The *opisthotic* nucleus lies at the inner side of the tympanic cavity and spreads to the lower part of the bone. The *proötic* is near the superior semicircular canal. The *epiotic*, arising near the posterior canal,

[1] Monatsschrift für Ohrenheilkunde, Bd. xiii, 1879.
[3] Joyce: Journal of Anatomy and Physiology, vol. xxxiv., 1900.
[2] Canalis facialis. [4] Canalis caroticus.

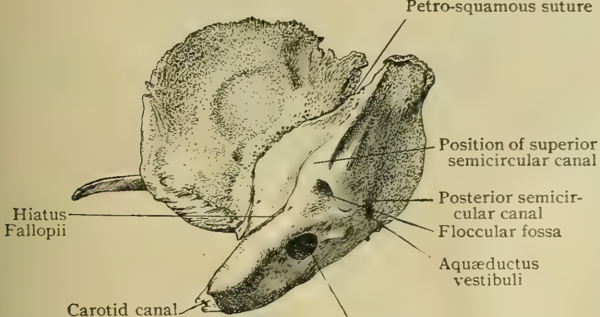
spreads into the mastoid portion. This one is sometimes double. There is also a separate nucleus for the tegmen, but this is not constant. When present, it seems to be the last to fuse with the others, which become one by the end of the sixth month. The carotid artery passes at first along the base of the skull in a groove which is made into a canal by the opisthotic. The separated petrous portion, when ossification has made some progress, shows a very prominent superior semicircular canal, and a deep cavity under it, extending backward from the inner surface. This is the *floccular fossa*, which, however, is completely hidden by the dura. The *mastoid process* becomes fairly distinct in the course of the second year. It develops greatly about the time of puberty, when it becomes pneumatic. This may occur much earlier. J. J. Clarke has seen it wholly pneumatic several times before the tenth year; once at three and a half.[1] The squamosal joins the petrous in the course of the first year.

FIG. 205.



Temporal bone at about birth, outer aspect.

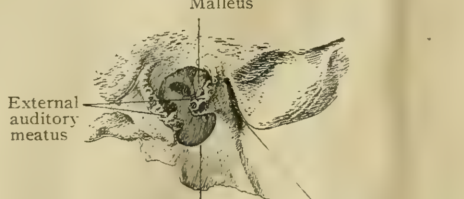
FIG. 206.



Temporal bone at about birth, from above and within.

At birth the *tympanic portion* consists solely of the imperfect ring open above. This enlarges trumpet-like from the edges, the front one forming the tympanic plate. The growth is of unequal rapidity, so that the lower part is left behind, presenting a deep notch the outer edges of which meet by the end of the second year, leaving a foramen below, which usually closes two or three years later, but exceptionally persists. The tympanic plate fuses almost at once with the petrous, but the Glaserian fissure remains; the groove showing the line of union of the tympanic and mastoid processes generally disappears in the second year, but occasionally persists through life. Kircher[2] found it present on both sides in five per cent. of 300 skulls. The *styloid process* consists of two parts. The first joins the petrous at about birth. The second, which represents all but the base, is an ossification of the stylo-hyoid ligament, and does not join till puberty or later. In very early fœtal life the chief vein returning the blood from the brain passes through the membrane that is to become the squamosal. This opening—the *foramen jugulare spurium*—is later of less importance, and is finally closed. In the skull, at birth, a pin-hole representing it may be found at the postglenoid tubercle. It is sometimes seen later.

FIG. 207.



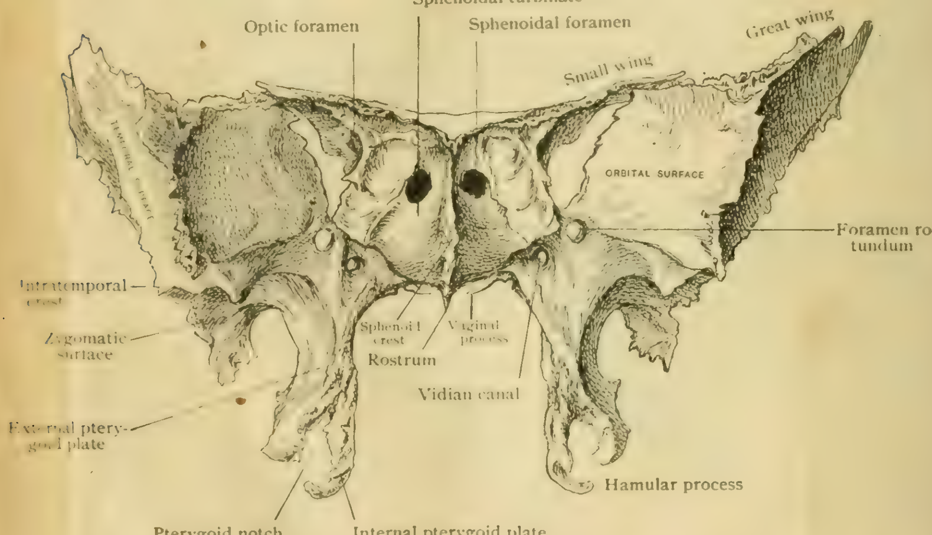
Tympanic portion of temporal bone in the second year.

[1] Journal of Anatomy and Physiology, vol. xxvii., 1893.
[2] Archiv für Ohrenheilkunde, Bd. xiv., 1879.

THE SPHENOID BONE.

In the adult this bone[1] consists of a cubical *body*, from the sides of which arise the *great wings*, from its front the *lesser wings*, and from below the *pterygoid processes*. Both development and comparative anatomy show that these parts represent several bones. The body consists of two parts, a posterior and an anterior. The posterior, the *basisphenoid*, is the centre of the middle fossa of the base of the skull; from its sides spread the *great wings*, or *alisphenoids*. These with the temporal bones complete the middle fossa. The anterior part, the *presphenoid*, inseparably connected with the basisphenoid, is in both the middle and the anterior fossæ. The *lesser wings*, the *orbito-sphenoids*, spread out from the presphenoid and cover the apices of the orbits. The *pterygoid processes* consist each of two plates, the inner of which represents a separate bone of the face, the outer being an expansion from the alisphenoid. Two bones called the *cornua sphenoidalia*, or *sphenoidal turbinates*, of independent origin, ultimately form a part of the body of the sphenoid.

FIG. 208.



The sphenoid bone from before.

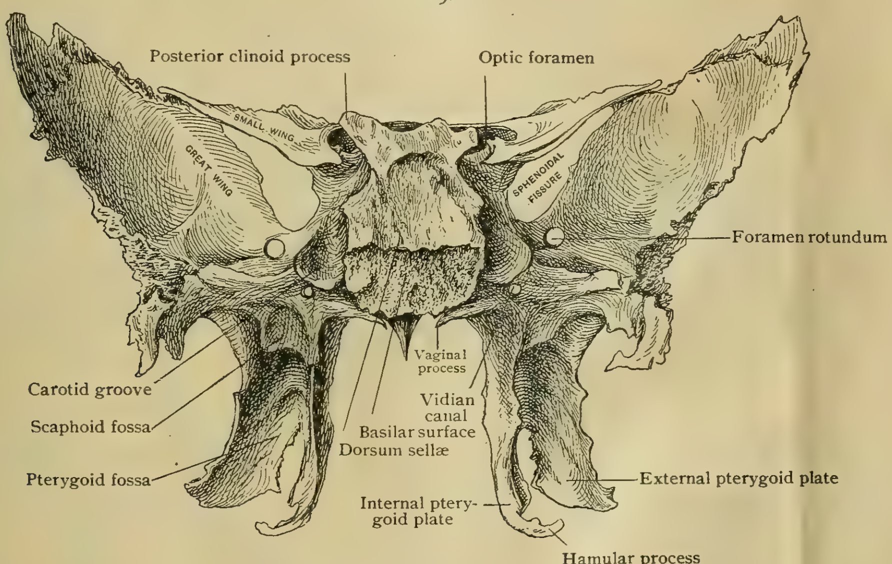
The Body.—It is necessary to describe the *basisphenoid* and the *presphenoid* together, since they form the roughly cubical body. The **superior surface** contains the deep *pituitary fossa*,[2] or *sella turcica*, in which hangs the pituitary body from the brain. Behind it is the *dorsum sellæ*, a raised plate continuous with the surface of the basilar process of the occipital and which completes the posterior fossa. Its outer angles are knobs pointing both forward and backward, the *posterior clinoid processes*, to which the tentorium is fastened. Beneath these, on either side of the dorsum, is a groove for the sixth nerve. In front of the sella is the *olivary eminence*[3] of the presphenoid, which is usually an oval swelling, though it may be plane or concave. At its sides grooves, often very poorly marked, lead to the *optic foramina*. The posterior edge of this eminence is sometimes grooved for a vein and sometimes sharp. Its lateral ends may become tubercles, the *middle clinoid processes*. The olivary eminence is in most cases bounded in front by a transverse elevation connecting the lesser wings, of which, indeed, it is a part, forming, when present, the separation of the anterior and middle fossæ. The front border presents in the median line a triangular point, the *ethmoidal spine*.

At each **lateral surface** of the body is the *carotid groove*[4] for the internal carotid artery. It is well marked only at the posterior edge, where the artery enters

[1] [illegible]sphen[illegible]le. [2] [illegible] [illegible]. [3] Tub[illegible] [illegible]ellae. [4] Sulcus [illegible]roticus.

it from the apex of the petrosal. It is here bounded internally by a little tubercle, the *petrosal process*, at the base of the dorsum, and externally by a very delicate plate, the *lingula*, which sometimes projects considerably; these two processes touch either side of the end of the carotid canal in the petrous. The rest of the side of the body is hollowed for the *cavernous sinus*, in which the carotid artery runs. It is covered below by the origin of the great wing. The **posterior surface** of the body is rough up to puberty for the cartilage that binds it to the basilar process of the occipital; later these parts coössify, and thereafter the posterior surface is made artificially by the saw. The **anterior surface** presents in the middle a sharp ridge, the *sphenoidal crest*,[1] to join the vertical plate of the ethmoid. Just at the sides of this the bone is smooth and aids in forming the wall of the nasal fossa. In each lateral half is an opening, the *sphenoidal foramen*,[2] into the cavity of the bone. The **inferior surface** presents in the middle a longitudinal swelling, thick behind, narrow and sharp in front, the *rostrum*, fitting into the vomer and usually joining the lower edge of the crest without interruption. It may stop short of it. On either side of the rostrum there is a smooth triangular surface made of delicate plate, which extends up onto the front, forming the smooth surface beside the crest, and bound-

FIG. 209.



The sphenoid bone from behind.

ing a large part of the hole into the antrum. These are the *bones of Bertin*, or *sphenoidal spongy bones*, of which more is to be said under Development (page 191).

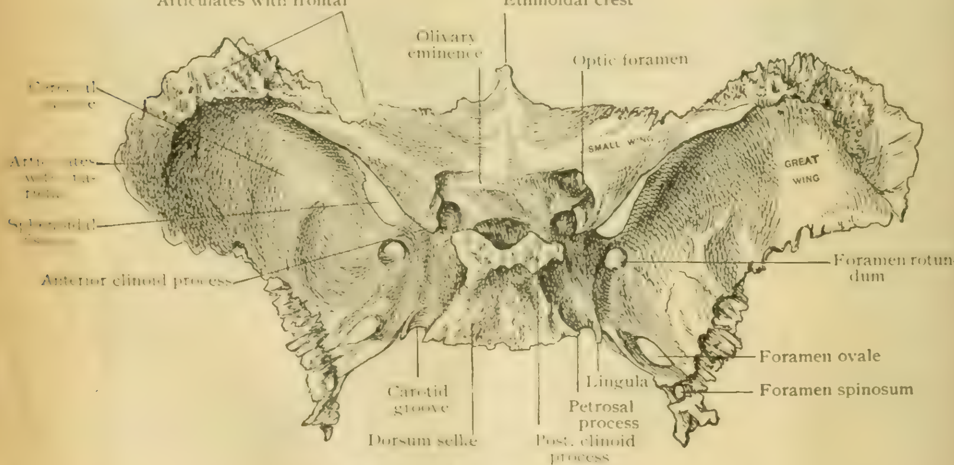
The body of the sphenoid is hollow, enclosing two cavities, the **sphenoidal sinuses**, separated by a septum, which runs obliquely backward from the crest, so that one sinus is usually much larger than the other. These sinuses have irregular ridges partially subdividing them. They are lined by mucous membrane and open into the nasal cavity by the sphenoidal foramina. The opening is reduced when the ethmoid is in place.

The **great wings**[3] have each a *cerebral* or *superior* surface forming a large part of the middle fossa, an *external* surface looking outward into the temporal and downward into the zygomatic fossa, and an *orbital* surface forming most of the outer wall of that cavity. The **superior surface** is smooth and concave; springing from the side of the basisphenoid, it spreads upward and outward and also backward to fill the gap between the petrous and squamosal parts of the temporal. By the side of the body there is a short canal running forward to open on the front of the bone into the spheno-maxillary fossa; this is the *foramen rotundum* for the superior maxillary division of the fifth nerve. A little further back and more internal is a pin-

[1] Crista sphenoidalis. [2] Apertura sinus sphenoidalis. [3] Alae magnae.

inside, the *foramen of Vesalius*, for a minute vein. Farther back and outward near the angle is the *foramen ovale*, transmitting the mandibular division of the fifth cranial nerve to the base of the skull, and admitting the small meningeal branch of the internal maxillary artery. Just beyond this, in the extreme angle, so as sometimes to be completed by the temporal, is the *foramen spinosum*, admitting the middle meningeal artery to supply the bone and the dura. The **external surface** is divided into a larger, superior, vertical part, looking towards the temporal fossa, and one looking into the zygomatic fossa. These are separated by the *infratemporal crest*, which near the front points downward as a strong prominence, the *infratemporal spine*. The inferior surface contains the foramen ovale and the foramen spinosum. Just behind the latter, at the posterior angle, is the *spine of the sphenoid*, pointing downward, grooved at the inner side by the chorda tympani nerve. The external surface has an anterior border where it meets the orbital surface, which joins the malar. The superior border slants upward, overlapping the frontal and parietal bones. The posterior border is about vertical as far down as the infratemporal crest, and bevelled, especially above, to be overlapped by the squamous part of the temporal. The lower part of this border runs backward and somewhat overlaps the squamosal. The posterior border of this surface, from the spine to the

FIG. 210.



The sphenoid bone from above.

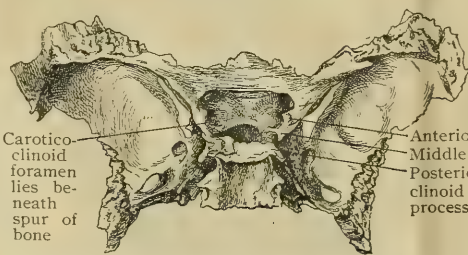
body, is slightly rough for the petrous, making with it a groove on the under side for the cartilaginous Eustachian tube. The smooth **orbital surface**, facing inward and forward, is quadrilateral, broader in front than behind. Almost the whole of it is in the outer wall of the orbit, of which it forms the greater part; but a small portion, narrow behind and expanding in front, looks into the spheno-maxillary fissure, which bounds this surface below. It joins the malar in front. On the top of the bone there is a rough triangular region in the angle formed by the meeting of the external and orbital surfaces, on which the frontal bone rests. This is above the front half of the orbital plate. The remainder of the upper and the whole of the posterior border of the latter bound the *sphenoidal fissure*.[1] This cleft is an elongated aperture directed obliquely outward and upward between the great and lesser wings of the sphenoid, completed externally by the frontal. It opens anteriorly into the orbit and transmits the third, the fourth, the ophthalmic division of the fifth and sixth cranial nerves, and the ophthalmic veins. There is a small projection near the middle of the hind border for a ligament crossing the fissure and for the outer head of the external rectus.

The **lesser wings**,[2] forming the back part of the anterior fossa and of the roof of the orbit, arise by two roots. The superior is a plate covering the presphenoid; the inferior is a strong process from the side of the body. With the latter they

[1] Fissura orbitalis superior. [2] Alae parvae.

enclose a canal, commonly called the *optic foramen*,[1] for the optic nerve, which is accompanied by the ophthalmic artery. The length of the canal measured along the inferior root is about five millimetres. The length of the roof is greater, perhaps nearly twice as much, but it is variable from the uncertain development of that part of the bone; definite dimensions are, therefore, wanting. The vertical diameter, some five millimetres, of the opening into the orbit is a little greater than the transverse. The small wing overhangs the front of the middle fossa bounding the sphenoidal fissure above, and ends laterally in a sharp point. The *anterior clinoid process* is a sharp projection backward above the inferior root and towards the posterior clinoid. Sometimes it reaches the latter; sometimes it is connected by a spur with the *middle clinoid process*, then bridging the carotid groove and making a *carotico-clinoid foramen* (Fig. 211). The anterior border of the lesser wings is rough at its inner part and smooth at the outer, where it joins the posterior edge of the horizontal plate of the frontal. The posterior border is smooth, forming most of the boundary of the anterior and middle cranial fossæ.

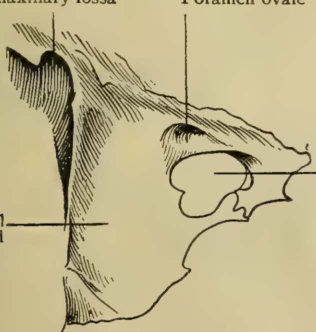
FIG. 211.



Sphenoid bone, showing abnormal development of middle clinoid processes, especially on the left side. Reduced one-half.

The **pterygoid processes**[2] are downward projections which, articulating with the palate bone, form the back of the framework of the upper jaw. Each consists of two plates, an inner and an outer, united in front, diverging behind to form the *pterygoid fossa*, and separating below on either side of the *pterygoid notch*. The inner springs from the body, the outer from the great wing. The **inner pterygoid plate**[3] is the longer. It is nearly vertical, ending in the slender *hamular process*[4] which points outward, bounding a deep little notch through which the tendon of the tensor palati plays. At the inner side of its origin the internal plate presents a scale-like curved projection, the *vaginal process*, above which is an antero-posterior groove below the body of the sphenoid, in which the lateral expansion of the base of the vomer is received. Just external to the vaginal process is another small groove, the *pterygo-palatine*, which the palate bone converts into a canal leading back from the spheno-maxillary fossa. The **outer pterygoid plate**[5] is broader and flares outward. The anterior surface of the root is nearly smooth, forming the back wall of the spheno-maxillary fossa. It has the openings of two canals: the upper and outer is that of the foramen rotundum; the lower and inner, which is smaller, is the *Vidian canal*, transmitting the nerve and vessels of that name. There is a vertical ridge between the two, and a slight groove below the latter, forming with the palate bone the beginning of the posterior palatine canal which runs from the spheno-maxillary fossa through the hard palate, transmitting a descending palatine nerve and vessels. The lower anterior edges of both plates are rough to articulate with that bone. The outer surface of the external plate is irregular for the origin of the external pterygoid muscle. The inner wall of the inner plate is smooth. It bounds laterally the back of the nasal cavity. The posterior borders of both plates are sharp, excepting that the inner is formed by the union of two lines which enclose the *scaphoid fossa* where the tensor palati arises. Rather less than half way down the internal plate presents a promi-

FIG. 212.

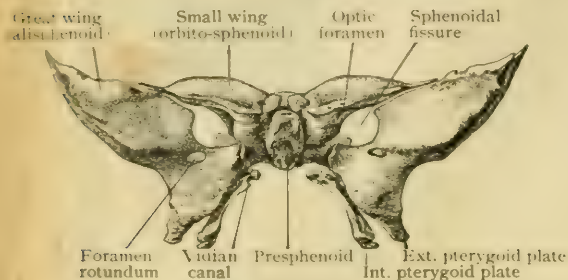


Portion of sphenoid bone, showing the foramen pterygo-spinosum.

[1] **Foramen opticum.** [2] **Processus pterygoidei.** [3] **Lamina medialis proc. pteryg.** [4] **Hamulus pterygoidei.** [5] **Lamina lateralis proc. pteryg.**

[illegible] bounding a groove below, which supports the Eustachian tube. The posterior border of the outer plate is irregularly scalloped. Near the top a transverse ridge crosses its inner surface; if well marked, this forms the top of the pterygoid fossa. It may be barely discernible (Waldeyer[1]). Just above the scaphoid fossa is the hind end of the Vidian canal opening into the middle lacerated foramen opposite the apex of the petrous. The development of the pterygoid plates varies greatly. The upper part of the outer may be prolonged to the spine of the sphenoid, just outside of the foramen ovale, with a perforation at this point, so that some of the branches of the third division of the fifth cranial nerve may pass on either side of it. This occurs by the ossification of a band of fibrous tissue, connecting the back of the plate with the spine, and thus forming the *foramen pterygo-spinosum* of Civinini (Fig. 212). This is always behind the foramen ovale, or internal to it. Just outside of the foramen is found, very rarely, a little canal on the under side of the great wing, transmitting a branch of the mandibular division of the fifth nerve, the *porus crotaphitico-buccinatorius* of Hyrtl.

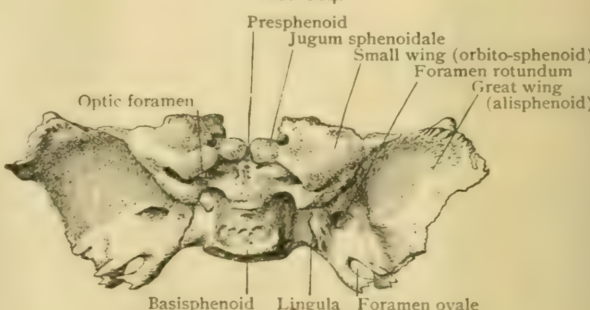
FIG. 213.



Sphenoid bone at about birth, seen from before.

Articulations.—Much has been already said incidentally on this point in the foregoing description. The sphenoid bone joins the occipital behind. The great wings send the spine into the entering angle between the squamous and petrous portions of the temporal. These two bones—the sphenoid and the temporal—form the entire middle fossa of the skull. The *middle lacerated foramen* is just behind the carotid groove at the side of the body and in front of the end of the petrous. At the side of the skull the great wings join the squamous behind, the parietal and the frontal above, and the malar in front. The ethmoid covers the front of the body of the sphenoid, its vertical plate joining the crest. The vomer covers the rostrum below. The palate bone fills up the pterygoid notch, completing the fossa, and by its sphenoidal process touches the edge of the body. The frontal bone joins the lesser wings.

FIG. 214.



Sphenoid bone at about birth, seen from behind.

Development.—The *presphenoid* and *basisphenoid* each ossify from a pair of nuclei, those of the former appearing at the end of the second month of fœtal life and the latter a little later. At about the eighth week a nucleus is to be seen in each of the greater wings near the body and extends outward, involving also the external pterygoid plate. The internal pterygoid plate has a nucleus of its own, which is present in the fourth month and joins the outer a month later. Two little granules appear in the fourth month for the lingula and a neighboring piece of the bone. The *orbito-sphenoids* have each two centres,—one on either side of the optic foramen. It would seem that the inner may in some cases take the place of those for the presphenoid. In any case the presphenoid and the lesser wings unite before birth. In the seventh or eighth month the presphenoid and basisphenoid unite, but at birth they are still separated by cartilage on their lower surface. *At birth* the bone con-

[1] Sitzungsber. Acad. Wissen., Berlin, 1893.

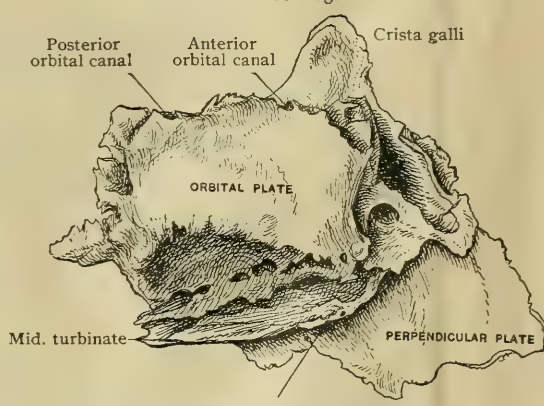
sists of the basisphenoid, the presphenoid, and the lesser wings in one piece, and a lateral one on each side,—namely, the greater wing and the pterygoids. The dorsum sellæ has a separate epiphysis which appears after birth. In the first year the lesser wings spread across the top of the presphenoid, joining the jugum sphenoidale, so that it does not show in the anterior fossa. The external pterygoid plate is an outgrowth of the great wing.

The *cornua sphenoidalia*, *bones of Bertin*, or *sphenoidal turbinate bones*, are two thin plates which appear before birth at the front of the presphenoid. They cover both the front and its inferior surface at the sides of the rostrum. At five years they are still free, but have approached their permanent shape of hollow cones. The hollowing out of the body of the sphenoid now begins, and at the same time the upper part of these bones is absorbed, so that the foramina become notches. These bones are ultimately joined to the sphenoid, the ethmoid, and the palate. Though usually reckoned as parts of the sphenoid, there is reason to believe that they are generally fused earlier with the ethmoid. The basisphenoid begins to coössify with the occipital at about the fifteenth year. The process is first completed above.

THE ETHMOID BONE.

The ethmoid[1] consists of a *median plate* forming a part of the nasal septum, of the *cribiform plate* joining it at the top on either side and forming the roof of the nasal cavity, and of two *lateral masses* attached to the lateral border of each cribriform plate, and touching the vertical plate very slightly just below its junction with the front of the cribriform plate. These lateral masses are roughly cubical, interposed between the cavities of the nose and of the orbit. They consist of a series of delicate plates forming the walls of air-spaces or cells, which are mostly completed by neighboring bones.

FIG. 215.



The ethmoid bone, outer aspect from the right side.

The **vertical** or **median plate**[2] projects near the front into the cranial cavity as the *crista galli*, thicker in front than behind, with an oblique upper border running sinuously downward and backward. Its greatest elevation is about one centimetre. The front part is occasionally hollow, forming a part of the frontal sinus. It gives attachment to the falx cerebri, a fold of dura separating the hemispheres of the brain. A little plate, *ala*,[3] facing downward and forward, arises from the front on either side, articulating with the frontal. Just before the crista galli is a pin-hole, the *foramen cæcum*, usually formed by both ethmoid and frontal, but which may be in either. It is said to transmit a vein in early life, but is closed later. The part of the vertical plate below the horizontal one is five-sided. The upper border runs along the base of the skull; one in front of it slants downward and forward under the nasal spine of the frontal, sometimes reaching the nasal bones; another descends nearly vertically along the crest of the sphenoid. Of the two inferior borders, the posterior runs downward and forward along the greater part of the vomer, while the anterior, running downward and backward to meet it, is free in the skeleton, but in life is attached to the triangular cartilage which forms a large part of the septum. The sides, covered with mucous membrane, are smooth except at the upper part, where there are vertical *grooves* for the olfactory nerves. This plate usually slants to one side.

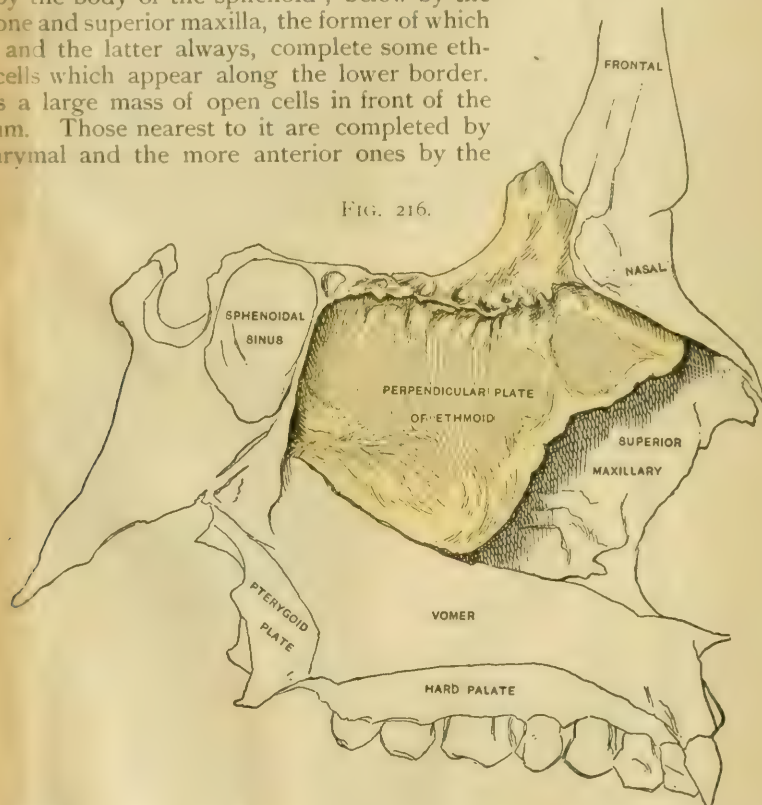
The **horizontal** or **cribriform plate**[4] forms the floor of a narrow groove on either side of the crista galli and, farther back, in the middle of the anterior fossa of

[1] Os ethmoidale. [2] Lamina perpendicularis. [3] Processus alaris. [4] Lamina cribrosa.

the skull. The greatest breadth of the groove is about five millimetres. It narrows in front to a point, and thus allows the lateral masses to touch the median plate. It supports the olfactory lobe of the brain, and is perforated by holes for the passage of the olfactory nerves. These are arranged rather vaguely in three rows. There are many in front and few behind. Many of the larger ones, which are near the septum or at the outer side, are small perforated pits. At the front a *longitudinal fissure*, close to the crista galli, transmits the nasal branch of the fifth nerve.

The **lateral masses**[1] are two collections of bony plates imperfectly bounding cavities. They are roughly six-sided, the greatest diameter being antero-posterior. The **outer surface** presents a vaguely quadrilateral plate, the *os planum*,[2] forming a large part of the inner wall of the orbit. In its upper border are two notches, which become the *anterior* and *posterior ethmoidal foramina* when the frontal bone is in place. The former transmits the nasal branch of the fifth nerve from the orbit to the cranial cavity. The os planum is bounded behind by the body of the sphenoid; below by the palate bone and superior maxilla, the former of which usually, and the latter always, complete some ethmoidal cells which appear along the lower border. There is a large mass of open cells in front of the os planum. Those nearest to it are completed by the lachrymal and the more anterior ones by the

FIG. 216.



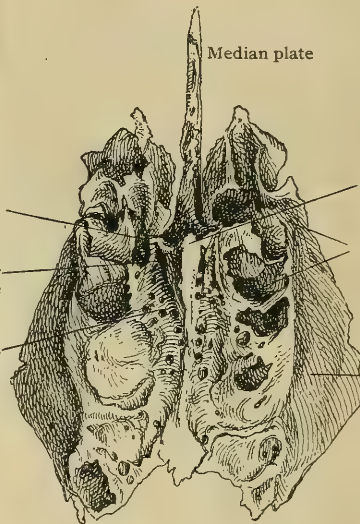
Median or perpendicular plate of ethmoid bone in place. The right lateral mass of the ethmoid has been removed.

nasal process of the superior maxilla. Posteriorly, the lateral mass rests against the body of the sphenoid, the posterior cells being separated from those of the sphenoid by the cornua sphenoidalia. The open cells on the upper surface of the lateral mass are closed by the imperfect cells on the under side of the horizontal plate of the frontal beside the *ethmoidal notch*. The few cells that open anteriorly are continuous with the lateral ones, and are closed by the nasal process of the upper jaw. The numerous spaces within the ethmoid are, for the most part, completed by the neighboring bones, after which they are named. There are some beneath the os planum, however, entirely within the ethmoid. The *ethmoidal cells*[3] are divided into *anterior* and *posterior*, of which the former open into the nose below the middle turbinate bone and the latter above it. The size and shape of the ethmodial cells are very irregular; sometimes the middle turbinate is hollowed into one, some-

[1] Labyrinthus ethmoidalis. [2] Lamina papyracea. [3] Cellulae ethmoidales.

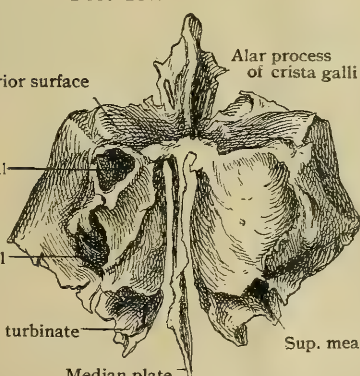
times they swell out into the cavities of other bones, notably into the frontal sinus. The **internal surface** of the lateral mass, forming the outer wall of the nasal cavity, cannot be seen on the entire bone. It is best studied on the bisected skull; but to study the whole bone, further cutting is necessary, since this surface is made of a series of convoluted plates, some of which conceal others. At least two of these—the *superior* and the *middle turbinate bones*[1]—are evident. They are curled with their convexities towards the median plane, so as to overhang two antero-posterior passages, the *superior* and the *middle meatus* of the nasal fossa. According to Zuckerkandl, there are three *ethmoidal* turbinate bones in more than eighty per cent., and sometimes four. When only two are seen, it is owing either to the absence of the second or to its slight development, so that it is hidden by the upper. It is certain that only two are evident in most cases, and we shall follow the usual method of so describing the bone.[2] The *inferior ethmoidal* (middle) *turbinate* is much the larger, very prominent, and joins the ascending process of the superior maxilla at the *crista ethmoidalis* or *superior turbinate crest*. Its general course is backward and downward, to end in a point at the posterior border of the bone. The free edge is so much curled under as to be hidden. The *superior turbinate* is much smaller, occupying the postero-superior angle. It appears to separate from the turbinate below it at about the middle of this surface. The *superior meatus*, which it overhangs, is therefore small. As above implied, an additional ethmoidal turbinate may appear from beneath it, and still another small one may very exceptionally be found above it at the extreme upper posterior angle. At the point at which the middle turbinate bone joins the nasal process of the maxilla there is often a slight elevation, the *agger nasi*, which is supposed to be the anterior end of another turbinate which passes under the preceding. When the middle turbinate is removed, a curved projecting plate, the *uncinate process*,[3] is seen on the lateral mass, curving downward and backward. It is some two or three millimetres broad and, extending beneath the rest of the bone, joins the inferior turbinate. The uncinate process, together with the agger, is held to represent the

FIG. 217.



The ethmoid bone from above.

FIG. 218.



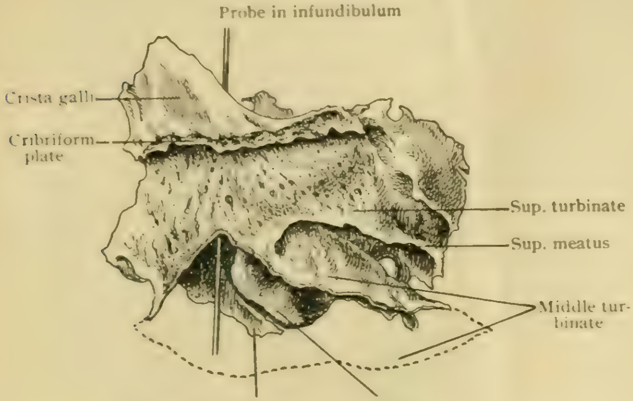
The ethmoid bone from behind, showing median plate and lateral masses.

[2] There are practically three turbinate bones, the upper two of which are parts of the ethmoid and the lowest a separate bone. These are called superior, middle, and inferior; hence we speak of the inferior ethmoidal turbinate as the middle one.

[1] Concha nasalis superior et media. [3] Processus uncinatus.

naso-turbinal bone of many mammals. Behind this is a globular swelling, the *bulla*,[1] formed by a plate springing from the os planum, covering cells, which also is held to represent a turbinate. Between the uncinate process and the bulla is a deep groove, the *infundibulum*,[2] curving downward and backward, the opening into which from the nasal fossa is known as the *hiatus semilunaris*. The upper end of the infundibulum opens into the frontal sinus in about half the cases,[3] ending blindly in the others; it is bounded externally to a varying extent by the lachrymal. A number of anterior ethmoidal cells generally open into this portion. The upper part of the infundibulum has an opening on its outer side into the antrum.

FIG. 219.



The ethmoid bone, inner aspect from left side, part of the middle turbinate having been removed.

Articulations.—These have already been described incidentally. Briefly recapitulated, however, the articulations of the ethmoid are with the frontal, the sphenoid, the palatals, the vomer, the inferior turbinates, the lachrymals, and the nasals.

Development.—The ethmoid is very small at first and backward in its development. About the middle of fœtal life ossification appears in the os planum and the middle turbinate bone. A centre (two, according to Poirier) for the vertical plate occurs in the first year, from which ossification extends into the crista galli. The cribriform ossifies chiefly (perhaps wholly) from the lateral masses. The date of the union of the three pieces is rather uncertain; it takes place, probably, at about the sixth year. The cells appear first as depressions during fœtal life. According to the more generally accepted view, their growth is by absorption of bone. It is hard to believe that this is not, at least, a factor; Poirier, however, holds that they are due to the course of ossification.

THE FRONTAL BONE.

This bone,[4] which forms the front of the vault of the skull, most of the floor of its anterior fossa, and bounds the greater part of the orbits and the ethmoidal cells above, is developed into two symmetrical halves which unite in the second year. It is convenient to divide the bone thus formed into a *vertical* and a *horizontal* portion, although this division rests on no scientific basis.

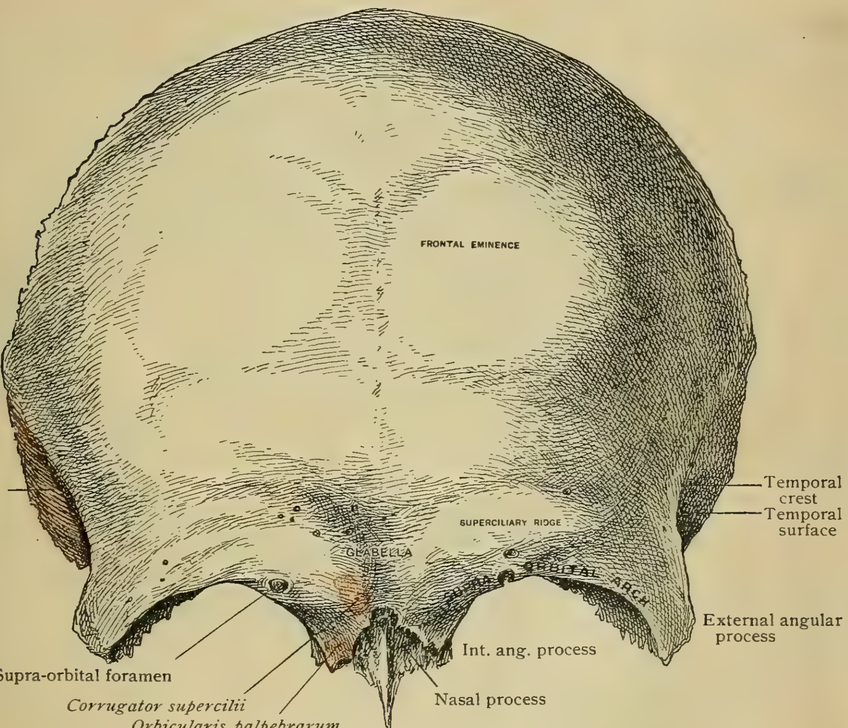
The **vertical portion**,[5] convex anteriorly, presents on either side, below its middle, the *frontal eminence*,[6] which represents the chief centre of ossification f either half. Very prominent in infancy, it diminishes during growth, and is hardly to be made out in most adult skulls. The lower border of the vertical portion grows downward in front between the orbits. At the sides of this projection are the *internal angular processes* of the orbits. In the middle-line a faint zigzag line marks the remnant of the *interfrontal suture*. Above this is a smooth, rather prominent surface, called the *glabella*, external to which are the *superciliary ridges*,[7] or *eminences*, which extend outward, somewhat above the inner ends of the orbits. The development of these varies greatly. On either side of the nasal projection is the *orbital arch*, extending outward from the internal angular process. At about the

[3] H. A. Lothrop: Annals of Surgery, vol. xxviii., 1898.

[1] Bulla ethmoidalis. [2] Infundibulum ethmoidale. [4] Os frontale. [5] Squama frontalis. [6] Tuber frontale. [7] Arcus superciliares.

inner third of the arch is the *supraorbital notch*[1] for the nerve and the artery of the same name. The outer edge of the notch is more prominent than the inner. Very often this is replaced by a *foramen*, which may be four or five millimetres above the edge of the bone. The arch ends externally in the *external angular process*,[2] which joins the malar and is very prominent. From it springs the *temporal crest*,[3] which, curving upward and backward, separates the anterior surface of the bone from the lateral one, which is a part of the temporal fossa. This crest generally, before leaving the bone, divides into *two lines*, of which one is much more distinct than the other. The vertical part of the bone has a slight point above in the middle and a very jagged posterior border interlocking with the parietal. The latter is slightly overlapped above and overlaps below. The bevelled, though jagged, articular surface broadens below to meet a triangular rough space on the inferior surface. At the lower lateral edge the bone is covered by the top of the great wing of the sphenoid.

FIG. 220.



The frontal bone from before.

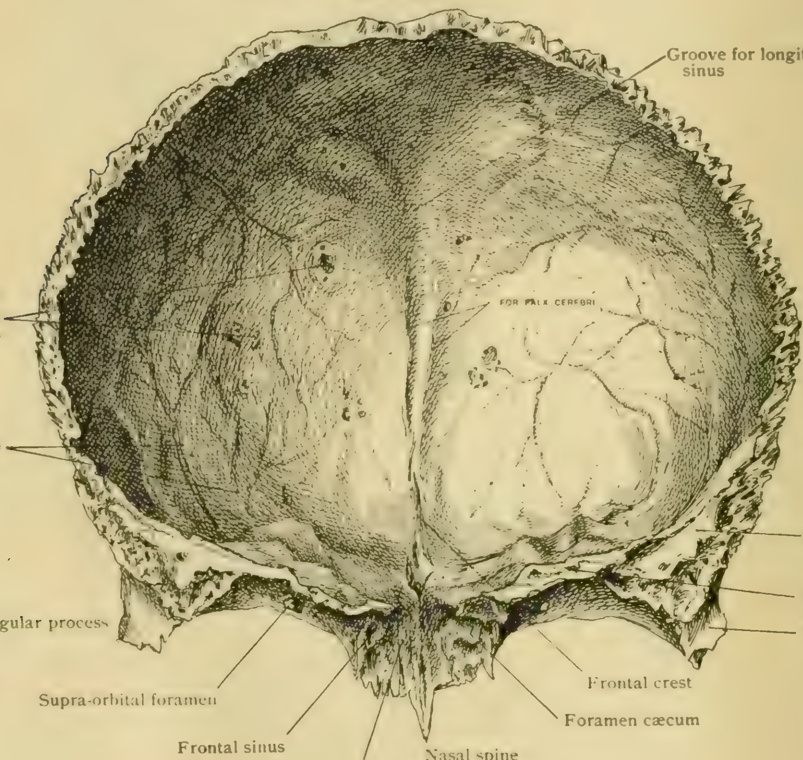
The **horizontal portion**[4] shows in the middle of its lower aspect a rough surface extending onto the front, called the *nasal process*, which articulates anteriorly with the nasal bones and laterally with the ascending processes of the upper jaw. In the middle projects a thin plate, the *nasal spine*, behind and between the nasal bones. On either side of this there is often found a small smooth surface forming a small part of the roof of the nasal cavity. Behind this lies the median *ethmoidal notch*,[5] on either side of which is an irregular space reaching to the inner edge of the orbit, made of imperfect cells, completing the ethmoidal ones. In front of these a cavity extends directly up, hollowing out the bone into the *frontal sinus*, which may extend outward and backward over the orbits. A partition separates the sinuses of the two sides, which are rarely symmetrical. The sinus opens into the middle meatus either directly, under the front of the middle turbinate, or through the infundibulum. When the ethmoid is in place, the cribriform plate and the crista galli fill up the ethmoidal notch; the ethmoidal cells are then closed, and the ethmoidal foramina

[1] Incisura supraorbitalis. [2] Processus zygomaticus. [3] Linea temporalis. [4] Pars orbitalis. [5] Incisura ethmoidalis.

and canals are formed. External to this lies the *orbital plate*, the front of which is overhung by the supraorbital arch. It is slightly concave from side to side. Just under cover of the external angle is an ill-marked *depression*[1] for the lachrymal gland. Near the internal angular process there may be a small *fossa*[2] for the cartilaginous pulley for the superior oblique muscle. More frequently there is a minute tubercle. The inner border of the orbital surface runs nearly straight backward. Its sharp edge articulates from before backward with the ascending process of the maxilla, the lachrymal, and the ethmoid. The outer edge runs obliquely inward. External to it, behind the angular process which joins the malar, is a rough triangular surface articulating with the great wing of the sphenoid. The posterior border of the orbital plate is short and serrated to join the small wings of the sphenoid.

The **internal surface** of the frontal presents the *frontal crest* below in the

FIG. 221.



The frontal bone from behind.

median line. It is a slight ridge, to which the falx is attached. A narrow *groove* runs along it, starting at the *foramen cæcum*, a hole either in this bone or between it and the ethmoid. This groove is for the superior longitudinal sinus. After a short distance the crest disappears, but the groove broadens and extends to the top of the bone. There are a few grooves for branches of the middle meningeal artery at the side and some small Pacchionian depressions.[3] Below, on either side of the notch, are the *orbital plates*, which slant strongly downward and inward, so as to leave the ethmoid in a deep gutter. Their upper surfaces are very irregular with so called *digital impressions* for the opposed cerebral convolutions. It is now evident how the frontal, the ethmoid, and the lesser wings of the sphenoid form the anterior fossa of the skull.

[3] See Parietal Bone (page 198).

[1] Fossa glandulae lacrimalis. [2] Fovea trochlearis.

Articulations.—The frontal articulates with the nasal, superior maxillary, lachrymal, malar, ethmoid, sphenoid, and parietal bones.

Development and Changes.—The only important centres are the two symmetrical ones appearing in the membrane at the frontal eminences towards the end of the second month of fœtal life. There is a separate point for the nasal spine and one near each angular process of the orbit. These smaller ones are fused in the seventh month of fœtal life. There is a centre for the posterior angle (Gegenbaur), which also unites before birth. The median (*metopic*) suture usually closes towards the end of the second year, and a year or two later is hardly to be recognized, except by the rudiment at the lower end. Occasionally the suture persists ; in that case it remains in extreme old age after the others have vanished. Not very rarely in the fœtus or infant a dilatation of the fissure, *metopic fontanelle*, is found near the upper part of its lower third. There are a few cases of traces of this in the adult.[1] The frontal sinuses appear about the seventh year and increase up to adult life. Later they are said to grow again, since in the latter part of life the inner table of the skull follows the shrinking brain. As their size is dependent chiefly on the behavior of the inner table, we can infer little about it from the shape of the forehead, unless the superciliary eminences are very prominent.

THE PARIETAL BONE.

The two parietal bones[2] complete the vault of the skull. Each is a thin quadrilateral bone with an inner and an outer table separated by diploë. Near the middle

FIG. 222.

Right parietal bone, outer surface.

on the convex **external surface** is the *parietal eminence*,[3] where ossification begins. It is very prominent in childhood, but, as a rule, is not very evident in the adult. Crossing this surface below the middle are two *curved lines*[4] continuous with those

[1] Schwalbe : Zeitschrift für Morph. und Anthrop., Bd. iii., 1901.

[2] Ossa parietalia. [3] Tuber parietale. [4] Linae temporales

into which the temporal crest of the frontal divides. The *superior* crosses the bone, ending at its posterior border. The *inferior* turns down towards the posterior part so as to reach the lower border to become continuous with the supramastoid crest of the temporal. In the middle of their course the lines are about two centimetres apart. The space between them is a little smoother than the surface above and below. It is uncommon to be able to trace both lines throughout. The inferior is usually the better marked. Sometimes a part of each is suppressed. The identity of a single line is shown by its termination. Near the upper posterior angle is a minute pin-hole, the *parietal foramen*,[1] which transmits a vein. This foramen is very often wanting, and, when visible, may be closed. In very rare cases it is a large hole, which may even admit a finger. It is occasionally double. The **internal surface** is smooth and glistening, as is the case throughout the inside of the cranium. It is marked by tree-like *grooves* for the branches of the middle meningeal artery.

FIG. 223.

Right parietal bone, inner surface.

One of these starts close to the anterior lower angle, being at first very deep and sometimes a canal for a short distance. Its situation is exceedingly constant. One or two other branches appear in the posterior half of the lower border. The superior longitudinal sinus rests in a groove[2] completed by both bones along the upper border. This groove is rarely symmetrical, being generally largest on the right. At the posterior inferior angle there is a small surface completing the groove[3] of the lateral sinus at the point at which it turns from the occipital into the temporal bone. *Pacchionian depressions* are small pits of varying size and number, found in the upper part of the inner surface, and most commonly near the groove for the longitudinal sinus, which contain the Pacchionian bodies of the arachnoid. The largest might receive the tip of the little finger.

The anterior, superior, and posterior borders are all jagged. The *anterior border* meets the frontal, overlapping it below, overlapped above. The *superior border* meets that of its fellow. The serrations are most developed in the middle,

[1] Foramen parietale. [2] Sulcus sagittalis. [3] Sulcus transversus.

the end of the suture behind the parietal foramina being nearly straight. The *posterior border* interlocks with the squamous portion of the occipital by a very irregular line of suture. The *inferior border*, concave in the middle, is bevelled on its outer surface, except behind. It is covered anteriorly by the top of the great wing of the sphenoid, and along the concavity by the squamous part of the temporal. The posterior portion presents a point at the back of the concavity which fits into an angle between the squamous and mastoid parts of the temporal. Behind this it is thick and jagged for the top of the mastoid portion. The *anterior superior corner* is about a right angle. The *inferior* one is somewhat drawn out. The *superior posterior corner* is rounded. The *inferior* is cut off.

Parietal impressions is the term applied to depressions which are observed very exceptionally on the outer surface of the parietal bones above the parietal eminences and near the upper border. They are usually large,—*i.e.*, some seven centimetres long by five or six centimetres broad. Some sections have shown that they involve only the outer surface of the bone. A thinning above the sagittal suture has also been observed, and even one over the lambdoidal suture. These latter are generally considered atrophic changes occurring in old age. The same explanation is offered for the parietal impressions proper, and very possibly with justice ; still, the case is reported by Shepherd[1] of an old woman who remembered having them all her life, and who declared that her father had them likewise. This would point to their being occasionally both congenital and hereditary. The late Professor Sir George Humphry[2] observed them in the orang-outang.

Articulations.—Each parietal articulates with its mate, the occipital, temporal, sphenoid, and frontal bones.

Development.—A single centre appears in the membrane at the end of the second fœtal month. According to Toldt (*Lotos*, 1882), this is double, consisting of an upper and a lower part, which soon fuse. The centre becomes very prominent, and bone-rays extend from it, making the bone very rough till after birth. The fontanelles at the four corners of the bone are discussed in describing the skull as a whole (page 231). The radiating lines of bone leave an interval near the back of the upper border of the bone, called the *sagittal fontanelle*, which closes during the latter part of fœtal life. According to Broca, this can be seen at birth once in four times. The parietal foramen is left as this fissure closes. Its occasional great size is accounted for by irregularities in the process. Very rarely a suture divides the parietal into an upper and a lower portion.

THE FACE.

The face consists of the *orbits*, the *nose*, and the *jaws*. Portions of the sphenoid and the ethmoid form a considerable part of it, as has been described. The facial bones are two *superior maxillæ*, two *malar*, two *nasal*, two *lachrymal*, two *palate*, two *inferior turbinates*, the *vomer*, the *inferior maxilla*, and the *hyoid*. The future *nasal septum*, extending in the median plane from the base of the skull to the upper jaw, is very early developed in cartilage. Ossification progresses from superficial centres on either side. These form the vertical plate of the ethmoid and the vomer ; but a considerable part, the triangular cartilage, remains cartilaginous.

THE SUPERIOR MAXILLA.

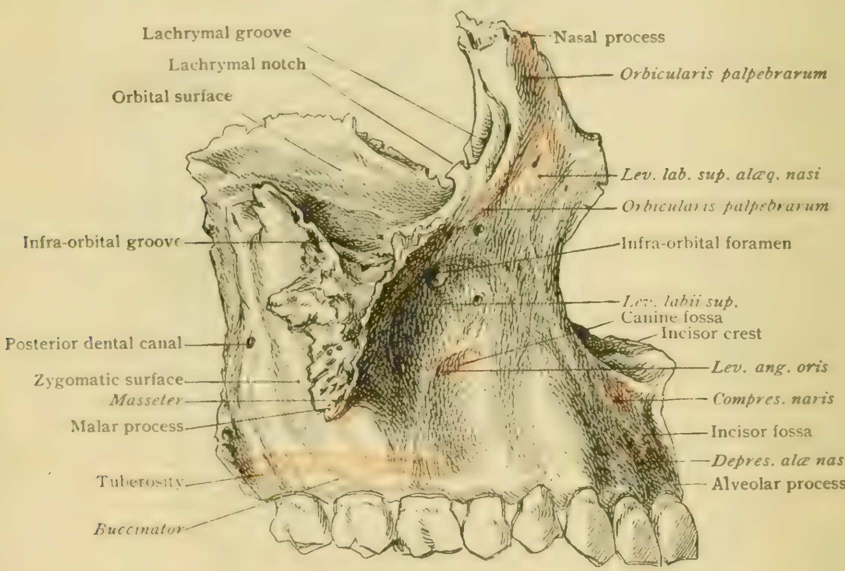
The superior maxilla[3] is a very irregular bone, which with its fellow forms the front of the upper part of the face, the floor of the orbit, much of the outer wall and floor of the nasal cavity, much of the hard palate, and supports all the upper teeth. It has a *body*, and *malar*, *nasal*, *alveolar*, and *palatal processes*. The general shape of the **body**[4] is that of a four-sided pyramid ; the base looking towards the nasal cavity, one surface forming the floor of the orbit and the other two the front and back of the bone. These three surfaces meet at the apex, which is the *malar process*.[5]

[1] Journal of Anatomy and Physiology, vol. xxvii., 1893.
[2] Ibid, vol. viii., 1874.

[3] **Maxilla.** [4] **Corpus maxillae.** [5] **Processus zygomaticus.**

This is a rough triangular surface articulating with the malar, often perforated, and sending downward a smooth ridge separating the anterior and posterior surfaces; the former is in the front of the face, the latter in the zygomatic fossa. The lower border of both is the *alveolar process*,[1] which is simply a curved row of tooth sockets made of very light plates of bone, which are absorbed after the loss of the teeth. The *palatal process*[2] joins the inner side of the body like a shelf and supports the anterior part of the alveolar process. The *nasal process*[3] rises from the anterior inner part to meet the frontal bone. In certain parts of the description it is convenient to disregard these subdivisions. The **anterior surface** of the bone forms the lower and outer boundary of the nasal opening, which is finished above by the nasal bone. On the entire skull this aperture resembles an ace of hearts inverted. The lower boundary of the opening is slightly raised and smooth. On the side it is sharp. The pointed *anterior nasal spine* projects forward where the two bones meet below the opening.[4] There is a slight depression—the *incisor* or *myrtiform fossa*—over the lateral incisor tooth. External to this is a ridge caused by the socket of the canine tooth. Farther outward is a well-marked hollow, the *canine fossa*. Above

FIG. 224.



Right superior maxillary bone, outer surface.

this, about five millimetres below the edge of the orbit, is the *infra-orbital* foramen, transmitting the nerve and artery of the same name. This surface is bounded above and externally by the malar process.

The **zygomatic surface** is in the main convex, except for a smooth concavity behind the malar process. The lower posterior portion, the *tuberosity*,[5] is rough, and presents at its upper part two or three minute *posterior dental foramina*[6] by which those nerves enter canals in the bone. The smooth **superior** or **orbital surface**, slanting a little downward and outward, is triangular. The posterior border is free, forming the lower limit of the spheno-maxillary fissure, and running obliquely forward to the malar process. The anterior border passes outward and backward to the same. The inner border is in the main antero-posterior. The hind end slants outward, articulating with the little triangular orbital surface of the palatal. Anterior to this, the border joins the os planum of the ethmoid; and anterior to the latter, at the base of the nasal process, lies a semicircular indentation, the *lachrymal notch*,[7] the posterior border of which touches the lachrymal bone. The deep *infra-orbital groove*[8] runs more than half across the orbital surface from behind, and then

[4] For a more detailed account, see the section on the Nasal Cavity.

[1] Processus alveolaris. [2] Processus palatinus. [3] Processus frontalis. [5] Tuber maxillare. [6] Foramina alveolaria. [7] Incisura lacrimalis. [8] Sulcus infraorbitalis.

becomes a canal, opening at the corresponding foramen in front. Occasionally a suture marks the course of the canal. The **internal wall** of the body presents on the separate bone a very large opening into the antrum, or maxillary sinus, which is much reduced when the other bones are in place. In front of this opening the wall is smooth and concave, forming a part of the lachrymal groove. Near the level of the top of the body there is the rough horizontal *inferior turbinate crest* for articulation with that bone. The wall at the back of this surface has a vertical groove, which, when the palate bone is in place, forms part of the *posterior palatine canal*, opening near the back of the hard palate and transmitting the descending palatine artery and the anterior palatine nerve.

The malar and the alveolar processes have been incidentally described. The *nasal* or *ascending process* rises at the inner side of the orbit. It is thin below, with an outer surface towards the face and an inner towards the nose. The top is thick and rough, joining the frontal. The *lachrymal groove*[1] for the tear-sac and the nasal duct begins on its outer surface and passes down behind it, making a deep notch at the front of the orbital plate. The lower part of the process extends down as far as the inferior turbinate crest, forming, with the lachrymal, the inner side of the groove. The point of junction of the front border of the groove with the orbital plate is usually marked by the *lachrymal tubercle*. The inner side shows above at the posterior border some cellular spaces completing the anterior ethmoidal cells, bounded below by a ridge, the *crista ethmoidalis*, which articulates with the front of the middle turbinate bone. Below it the bone is concave, forming part of the vestibule of the nose ; above it is plane and marked with vascular grooves.

The palatal process projects inward from the anterior two-thirds of the body and joins the alveolar process in front. It is very smooth above, the mucous membrane being lightly attached to it. It is slightly concave from side to side, and has a raised edge in front. It is also raised along the median line to form the *nasal crest*[2] with its fellow. The front of this ridge, called the *incisor crest*, suddenly rises to a higher level and juts out below the nose as the *anterior nasal spine*. The vomer rests on the ridge, except at the front, where its place is taken by the triangular cartilage. The under surface of the palatal process, horizontal behind, slants downward in front to the incisor teeth. It is rough for the firm support of the mucous membrane. The median surface of the palate is rough to join with its fellow. A little behind the incisors it shows a groove in the lower part, which becomes a canal in the upper, and opens into the floor of the nasal fossa of either side. Thus there are two canals above and one below, like a Y placed transversely. These are the *canals of Stenson*, which transmit an artery connecting the vessels of the nose and mouth. Their common orifice is called the *anterior palatine canal*.[3] Into this open two minute canals, the left anterior to the right, made by the junction of the bones. These are the *canals of Scarpa*, and transmit the naso-palatine nerves. They are by no means always to be found. The canals of Stenson represent the anterior palatine canal of lower animals, which in them is generally double throughout. In man the whole opening is usually closed by mucous membrane. The back of the palate process joins the horizontal plate of the palate bone, which completes the palate behind.

The **antrum** or **maxillary sinus**[4] is a large cavity within the body, the shape of which it follows in the main, although with many variations of size. The large opening on its inner wall is much diminished when the palate, the ethmoid, and the inferior turbinate are in place. It lies near the anterior end of the lateral wall of the middle nasal meatus, covered by the middle turbinate. A small part of the roof of the antrum is often formed by the palate bone, and sometimes the cavity extends into the malar. The inner and most of the posterior and outer walls are generally very thin, as is also the roof, except around the infra-orbital canal, which projects into the antrum. The development outward towards the malar bone varies much, as does the downward and forward growth towards the alveolar process. The lower border of the antrum is usually a trifle below the level of the floor of the nares. According to C. Reschreiter,[5] this is a male characteristic. Be that as it may, it certainly is in

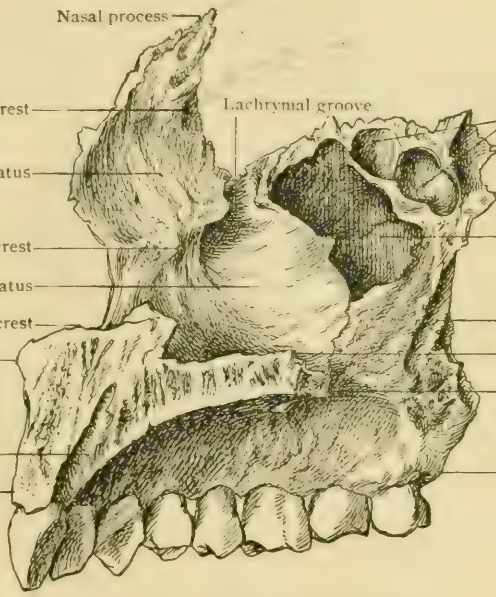
[5] Zur Morphologie des Sinus Maxillaris, Stuttgart, 1878.

[1] Sulcus lacrimalis. [2] Crista nasalis. [3] Foramen incisivum. [4] Sinus maxillaris.

accord with the larger size of the sinuses in man. The internal surface is largely smooth. Bony ridges springing from various parts tend to subdivide the cavity. They sometimes form little pockets above the teeth. According to Gruber,[1] it may in rare cases be completely subdivided into a smaller posterior chamber and a larger front one, both of which open into the nasal cavity. The lowest part of the antrum is indented by the roots of the molars and of the second bicuspid, at least very frequently. The first and second molars always indent it, but the bicuspid and the wisdom-tooth may not. (For further details, see Teeth, page 1556.)

Articulations.—All the bones of the face, except the lower jaw and the hyoid, touch the superior maxilla. It has been described as the key to the architecture of the face. The palate bone both completes the palate and lies between this bone and the pterygoids, closing the posterior part of the opening into the antrum. The malar, joining the process of that name, makes the prominence of the cheek and helps to bound the orbit. The nasals complete the anterior nasal aperture. The lachrymals and ethmoid touch the inner side of the orbital plate, and the ethmoid the inner surface of the nasal process. The frontal rests on the nasal process, the

FIG. 225.



Right superior maxillary bone, inner surface.

inferior turbinate rests on the inner surface of the maxilla, and the vomer on the crest made by the union of the palate processes.

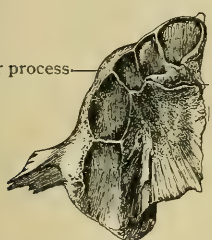
Development and Changes.—There are certainly four chief centres, all of which appear at about the end of the sixth week of fœtal life. Three of them fuse very rapidly. There is one on either side of the infra-orbital groove, a *malar* and an *orbito-facial*, and below and internally a *palatine*. The fourth, the *intermaxillary*, stays distinct longer. It comprises the front of the palate as far back as the anterior palatine canal, and represents a very constant separate ossification in vertebrates, the *premaxilla*, in front of the maxilla, except in certain mammals in which it is between them. It bears the incisor teeth, and at the third fœtal month fuses with the maxilla. As the intermaxillary grows, the suture in the roof of the mouth persists for a time. It is very plain at birth and often for a year or two later. Sometimes it is seen in the adult. At first the posterior suture is very close to the incisors, but as it grows the intermaxillary forms a large part of the palate. If detached, it is seen notched behind, so as to form the inner wall of the upper part of

[1] Virchow's Archiv, Bd. lxiii.

Stenson's canal. The suture is rarely seen above and never in front, being concealed by the plate forming the front of the bone. Albrecht[1] asserts that each intermaxillary is double. In support of this is the fact that in cleft palate the fissure does not always come between the incisor teeth and the canine, but an incisor may be found on its outer side. In reply to this it has been pointed out that three incisors on each side occasionally occur, and that, as anomalies are likely to be found in groups, this is merely an irregular arrangement. Moreover, in cases in which the cleft has but one incisor on each side of it, it is well argued that the original position of the tooth-sacs has no certain relation to the bones (Th. Kölliker[2]). In support of Albrecht is the occasional presence of a line subdividing the lower surface of the premaxilla ; but, on the other hand, it is not certain that this is really a suture, and there seems no evidence that the premaxilla has two centres of ossification. While there is much that is plausible in Albrecht's views, they cannot be considered as established.

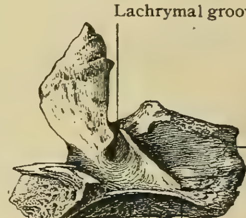
Sir William Turner[3] thus concludes an excellent discussion of the question : "What is yet wanted, however, to give completeness to the evidence of the division of the intermaxillary bone into an inner and an outer part is the discovery that the intermaxillary bone normally rises from two distinct centres of ossification, one for the inner, the other for the outer part. Of this we have at present no evidence.

FIG. 226.



Inferior surface of upper jaw at about birth.

FIG. 227.



Mesial surface of upper jaw at about birth.

But, in connection with this matter, we ought not to forget that it is quite recently that the embryological evidence of the origin of the intermaxillary part of the human upper jaw from a centre distinct from that of the superior maxilla has been completed. And yet for nearly a century, on such minor evidence as was advanced by Goethe, —viz., the suture on the hard palate extending through to the nasal surface,— anatomists have believed and taught that the human upper jaw represented both the superior and intermaxillary bones in any other mammal. Where a question in human embryology hinges upon an examination of parts in a very early stage of development, we often have to wait for many years before an appropriate specimen falls into the hands of a competent observer."

The upper and lower sides of the bone are at first very near together. The tooth-sacs are directly below the orbit. In the latter part of fœtal life the antrum appears as a slight pouch growing in from the nasal side. As the bone grows, the antrum remains for some time on the inner side of the infra-orbital canal. The outer part of the bone, especially towards the malar, is filled with diploë, which subsequently is absorbed as the sinus extends outward. By the end of the second year the cavity has extended above the first permanent molar ; by the twelfth or thirteenth year, when the second molar has appeared, the antrum approaches, though it has not yet reached, its definite shape. During the first dentition it is separated by the uncut teeth from the front of the bone.

[1] Sur les quatres os intermaxillaires, Soc. d'Antropol. de Bruxelles, 1883. Die morphologische Bedeutung der Kiefer-, Lippen-, und Gesichtsspalten, Langenbeck's Archiv, Bd. xxi.

[2] Ueber das Os intermaxillare des Menschen. Nova Acta der Leopold. Carol. Akad. der Naturforschen, Bd. xliii., 1882.

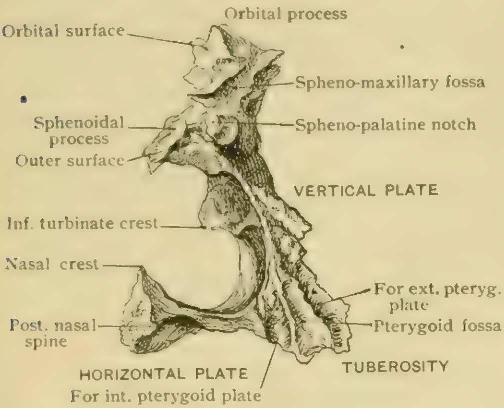
[3] Journal of Anatomy and Physiology, vol. xix., 1895.

After the loss of the teeth from old age or otherwise the alveolar process is absorbed. Senile atrophy is particularly marked in this bone.

THE PALATE BONE.

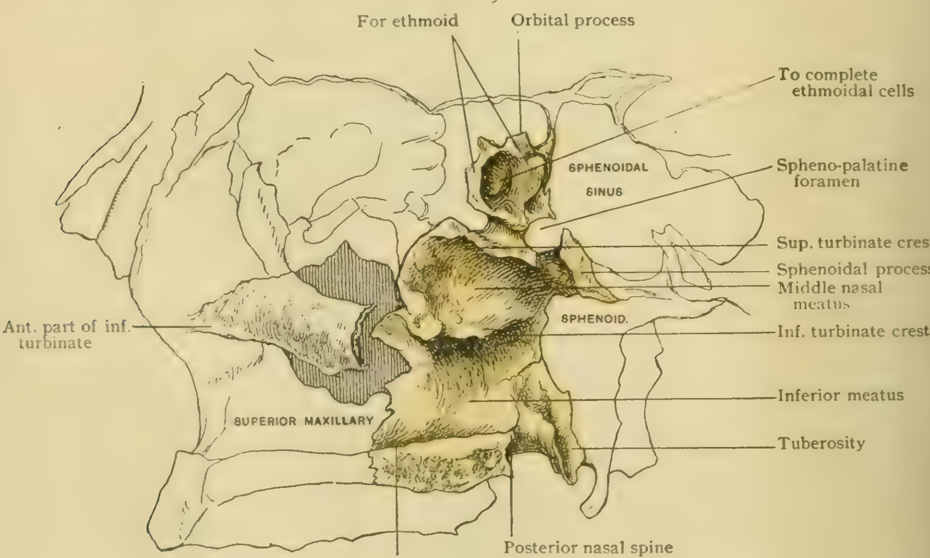
This[1] consists of a *horizontal* and a *vertical plate* and three processes, the *pyramidal*, the *orbital*, and the *sphenoidal*. The **horizontal plate**[2] is quadrilateral. It completes with its fellow the hard palate, filling the space left vacant between the back parts of the superior maxillæ. Its superior surface is smooth like the rest of the floor of the nares, and the lower rough, but less so than that of the superior maxilla. The anterior border fits the back of the palatal process of the maxilla; the inner border is rough to meet its fellow, and raised into a *nasal crest* meeting the back of the lower edge of the vomer. This is prolonged behind to form with the other the *posterior nasal spine*. The posterior border is smooth and concave from side to side. The outer border joins the **vertical plate.**[3] This is very thin, with an outer and an inner surface. It is surmounted by two processes, between which is a deep notch which forms three-quarters or more of the *spheno-palatine foramen*[4] when the bone is in position, so that both processes touch the body of the sphenoid. The outer surface presents near the top a smooth vertical surface forming part of the *pterygo-maxillary*

FIG. 228.



Right palate bone from behind.

FIG. 229.



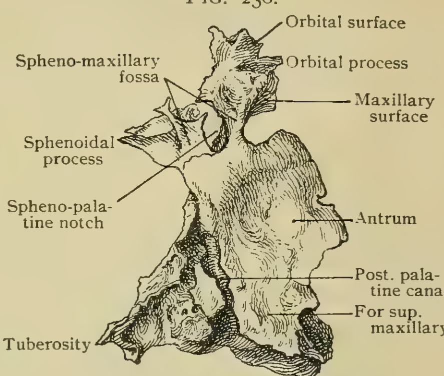
Inner aspect of right palate bone in place. Part of inferior turbinate removed.

fissure. This narrows below into a groove which makes the *posterior palatine canal* when applied to the corresponding groove in the maxilla. In front of this the surface is at first rough where it rests against that bone, and more anteriorly smooth where it closes the lower part of the opening of the antrum by an irregular

[1] Os palatinum. [2] Pars horizontalis. [3] Pars perpendicularis. [4] Foramen sphenopalatinum.

prolongation. The inner surface, looking towards the nasal cavity, is free and smooth. It is crossed below the middle by a ridge, the *inferior turbinate crest*[1] for the posterior attachment of the inferior turbinate bone. Nearly on a level with the base of the notch is another ridge faintly marked behind it; this is the *superior turbinate crest*[2] for the middle turbinate bone of the ethmoid. A small part of the top of the vertical plate looks into the superior meatus. The **pyramidal process,** or **tuberosity,** is the only solid part of the bone. It projects backward and somewhat outward from the lower part of the vertical plate. A smooth, hollowed, triangular surface fits into the space left between the pterygoid plates, completing the floor of the pterygoid fossa; on one side of this is a groove for the front of the internal pterygoid plate and on the other a rough surface for that of the outer. Thus, through the palate bone, the pterygoids support the back of the upper jaw. The outer side of the process rests against the tuberosity of the maxilla in front of the tip of the external pterygoid plate. The **orbital process,** is the anterior of the two processes above the vertical plate, the larger and higher, so called because it forms a small part of the floor of the orbit near its apex on the inner side. This little surface, on the outer side of the process, is triangular, one edge articulating with the upper jaw and one with the os planum, the hind edge being free. Another smooth surface looks outward and backward towards the spheno-maxillary fossa. It is separated from the preceding surface by an angle. Three other surfaces rest against other bones. An antero-inferior one joins the maxilla, sometimes helping to close the antrum; an anterior one touches the ethmoid, bounding part of a cell; and a small one, just at the top of the notch, touches the sphenoidal spongy bone. The posterior or **sphenoidal process** has a narrow upper surface, which, joining the sphenoidal spongy bone near the base of the internal pterygoid plate, completes the *pterygo-palatine canal.* This surface reaches the edge of the vomer. The internal surface, slanting a little downward, is free, looking into the nasal fossa. The outer surface is divided by a vertical ridge into an anterior part, free and smooth, looking into the spheno-maxillary fossa, and a scale-like posterior portion which rests against the external pterygoid plate.

FIG. 230.



Right palate bone, outer aspect.

The Spheno-Maxillary Fossa.—When the palate bone is applied to the sphenoid and the maxilla, the *spheno-palatine foramen* forms a window between the nasal chamber and a little hollow, the *spheno-maxillary fossa*, just below and behind the apex of the orbit. The posterior wall of this space, formed by the smooth surface of the sphenoid above the pterygoid plates, is pierced by the *foramen rotundum* and the *Vidian canal.* Below, it narrows funnel-like into the *posterior palatine canal.*

Articulations.—The palate bone articulates with its fellow, the superior maxillary, sphenoid, ethmoid, vomer, and inferior turbinate bones.

Development.—Ossification begins from a single centre appearing in membrane near the end of the second fœtal month at about the junction of the vertical and horizontal plates. It is very delicate throughout fœtal life, but the posterior free edge of the palate is very early much denser. Originally the horizontal plate is larger than the vertical one; at birth they are about equal.

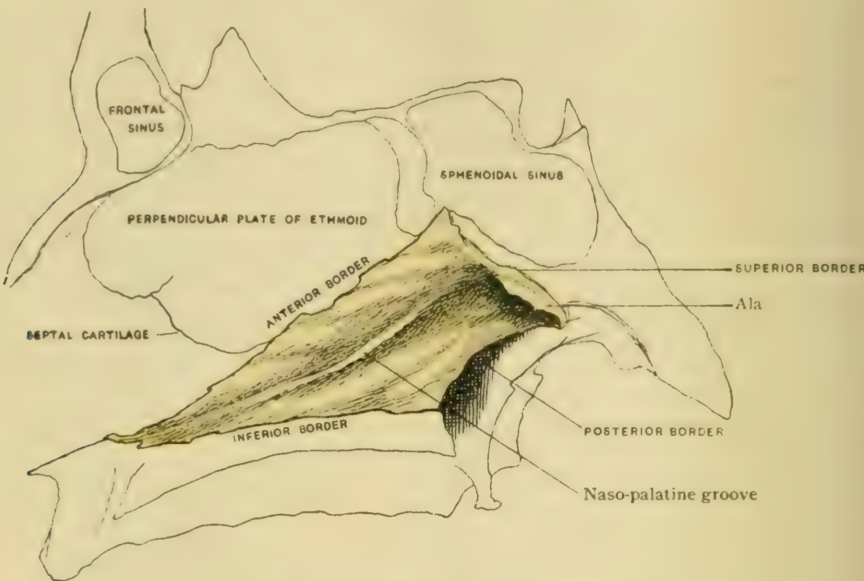
THE VOMER.

The vomer[3] is a thin, irregularly quadrilateral plate, forming the back and lower part of the nasal septum. The *superior border* expands laterally into two wings, or *alæ*, which articulate with the under surface of the body of the sphenoid, and enclose a medium groove for the rostrum. Laterally, the wings fit under the vaginal pro-

[1] Crista turbinalis. [2] Crista ethmoidalis. [3] Vomer.

cesses of the sphenoid. The *posterior border* is free. Thick above, just under the alæ, it soon narrows and runs downward and forward. The *inferior border* fits

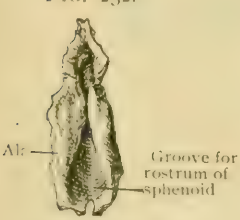
FIG. 231.



Vomer in place, from left side.

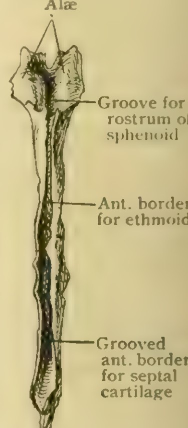
between the nasal crests of the palatals and maxillæ, and anteriorly changes its direction so as to rise over the higher incisor crests as far as the anterior palatine canal.

FIG. 232.



Vomer, superior surface.

FIG. 233.



Vomer from before and above.

The *anterior border* is the longest. Its upper part articulates with the back of the vertical plate of the ethmoid, the lower part with the triangular cartilage of the nasal septum. The latter is received into a groove which may extend behind the vertical plate. The *sides* of the vomer are covered with mucous membrane. They present a few irregularities, the most important of which is a *groove* on either side, nearer the front than the back, for the naso-palatine nerve; and, just anterior to this, a thickening which is normally insignificant, but occasionally is developed to one side or the other, forming a spur which may nearly close the passage.

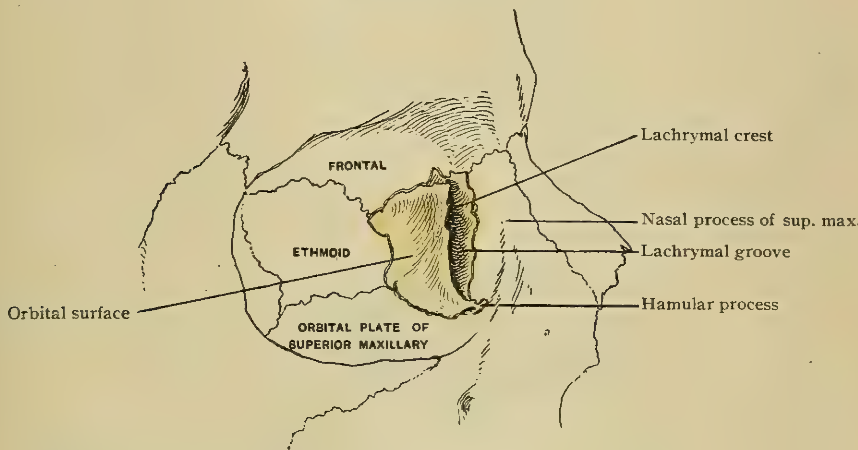
Articulations.—The vomer articulates with the sphenoid, ethmoid, palate, and superior maxillary bones and the median triangular cartilage.

Development.—It is to be remembered that, although the vomer becomes through ossification one of the separate bones of the face, at an early period it is but a portion of the septal cartilage without any hint of demarcation. A single centre appears before the close of the second fœtal month in the membrane at the under border of the cartilage, which then forms the septum. This grows upward on either side of the cartilage until the bone is complete. The young bone shows very clearly its formation in two plates; but in the adult this appears only in the groove between the wings and in the lower part of the front border, which still receives the triangular cartilage.

THE LACHRYMAL BONE.

The lachrymal bone[1] is an exceedingly thin osseous plate, filling the vacancy in the inner wall of the orbit between the orbital plate of the ethmoid and the ascending process of the superior maxilla. It is quadrilateral, the long diameter being vertical, and presents an *outer surface* directed towards the orbit and an *inner surface* towards the nasal fossa. The latter rests, in part, against the turbinate process of the ethmoid, which more or less overlaps it. It closes the infundibulum and several anterior ethmoidal cells. The lower and anterior portion of this surface forms a part of the wall of the middle nasal meatus. The outer surface is subdivided by a vertical ridge,[2] marking off a smaller anterior part, which forms the *lachrymal groove;*[3] and, joining the corresponding groove of the superior maxillary, complete the *lachrymal canal.*

FIG. 234.



Right lachrymal bone in place, outer aspect.

The posterior part of the orbital surface is plane. The *hamular process*[4] is a small tongue of bone curving forward from the lower part of the dividing ridge to form the posterior border of the canal at the floor of the orbit. The *descending process* is a downward prolongation of the grooved portion, forming part of the wall of the canal, and meeting the lachrymal process of the inferior turbinate. The bone also articulates with the frontal by its upper surface, and with the front of the os planum by its posterior border.

FIG. 235.

Right lachrymal bone, inner aspect. Upper part completes anterior ethmoidal cells, lower looks into middle nasal meatus.

Articulations.—The lachrymal articulates with the ethmoid, frontal, superior maxillary, and inferior turbinate bones.

Development.—Ossification is from a single centre said to appear in the eighth fœtal week, although the variations imply extra ones. Macalister[5] enumerates six separate ossicles which may occur about the bone. It varies greatly in size; it may be wanting, though rarely, and sometimes is very large. A considerable development of the hamular portion, which may be separate, represents the condition of prosimians and platyrhine apes.[6] It may be subdivided or perforated.[7]

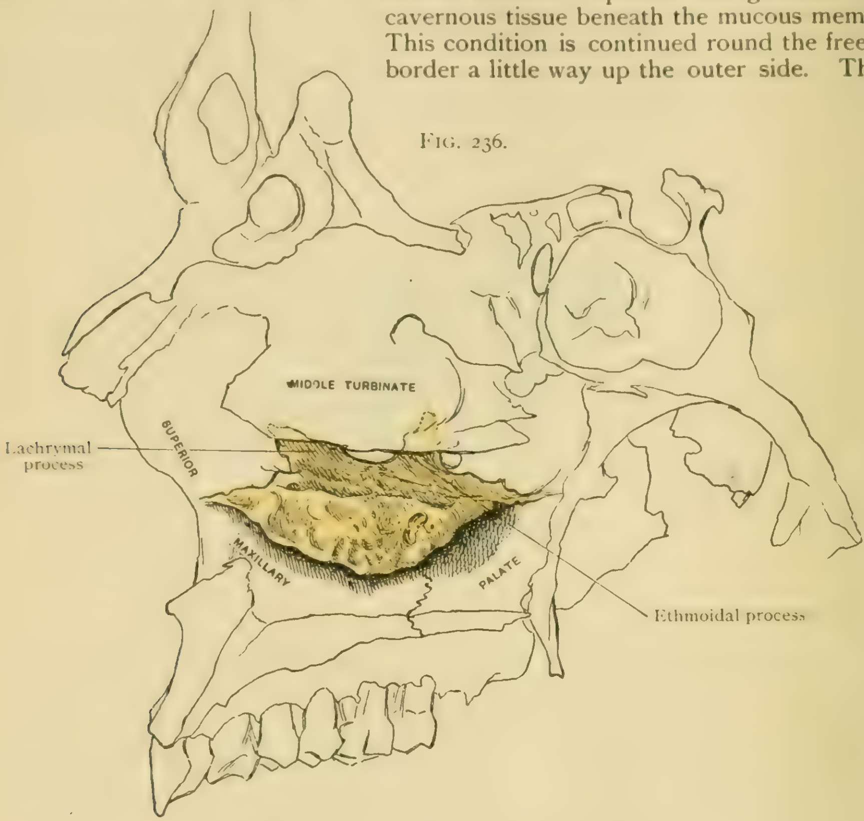
[5] Proc. Royal Society, 1884.
[6] Gegenbaur: Morph. Jahrbuch, Bd. vii.
[7] Le Double: Essai sur la Morphogénie et les Variations du Lacrymal, 1900; and Zabel: Varietäten und Vollstandiges Fehlen des Tränenbeins beim Menschen, Anat. Hefte. Bd. xv., Heft 1, 1900.

[1] Os lacrimale. [2] Crista lacrimalis. [3] Sulcus lacrimalis. [4] Hamulus lacrimalis.

THE INFERIOR TURBINATE BONE.

This is an elongated curved bone[1] placed in the lateral wall of the nasal cavity below the superior and middle turbinates, which are parts of the ethmoid. The inner convex surface is pitted and grooved by the cavernous tissue beneath the mucous membrane. This condition is continued round the free lower border a little way up the outer side. The rest

FIG. 236.



Right inferior turbinate bone in place, inner aspect.

of the outer surface, overhanging the inferior nasal meatus, is nearly smooth. The ends of the bone are pointed. They are connected below by the regular curve of the inferior border. The upper border is thin and irregular. It articulates in front with the inferior turbinate crest of the maxilla. Behind this rises the *lachrymal process*[2] —the highest—to meet the lachrymal bone. Posterior to this the *maxillary process*[3] bends outward and downward. It does not, however, usually hook over the upper edge of the plate bounding the entrance of the antrum, but meets it edge to edge, considerably reducing the opening. Still farther back is the *ethmoidal process*[4] meeting the uncinate process; and, finally, the border rests on the inferior turbinate ridge of the palate bone.

FIG. 237.

Right inferior turbinate bone, outer aspect.

Articulations.—The inferior turbinate articulates with the superior maxillary, ethmoid, palate, and lachrymal bones.

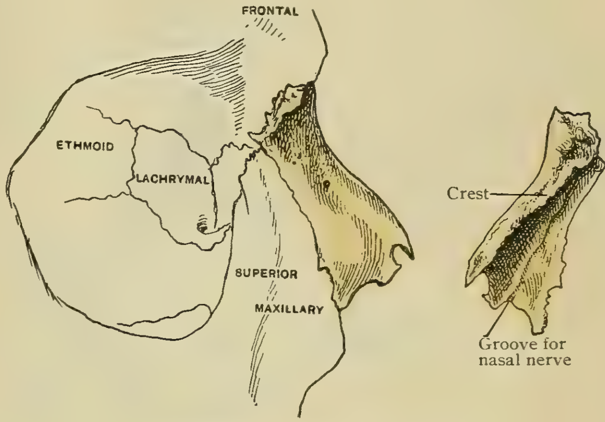
Development.—Ossification proceeds from a single center which appears about the middle of fœtal life.

[1] Concha inferior. [2] Proc. lacrimalis. [3] Proc. maxillaris. [4] Proc. ethmoidalis.

THE NASAL BONE.

The two nasal bones[1] bound the anterior nasal opening above. Each one is a four-sided plate with an outer and an inner surface. The upper end is thick and jagged, articulating with the frontal above and also behind. The anterior border, which articulates with its fellow, is thick above and thin below. When the two bones are in place, the united upper portions of these borders form posteriorly the *nasal crest*, which articulates with the nasal spine of the frontal, and sometimes with the vertical plate of the ethmoid below it. The posterior border joins the ascending process of the maxilla. The thin lower border, slanting downward and outward, has one or two indentations. The outer surface is broader below than above. It is depressed in the upper third, and has there a *foramen* for a vein. The extreme upper part of the inner surface is rough to join the frontal. Below this it is smooth where it forms the front of the nasal chamber ; the lower part of the inner surface sometimes seems hollowed out. A vertical *groove* for the nasal nerve ends near the notch in the lower border.

FIG. 238.



Right nasal bone, outer and inner aspects.

Articulations.—The nasal bone articulates with the frontal, ethmoid, superior maxilla, and the opposite nasal.

Development.—Ossification spreads from a centre appearing about the eighth week of fœtal life. At first the bone is broad and short. Occasionally a little Wormian bone is found in the median line between the nasals and the frontal. The two bones sometimes coössify, after the fashion of apes. Either a vertical or a transverse suture may be found.

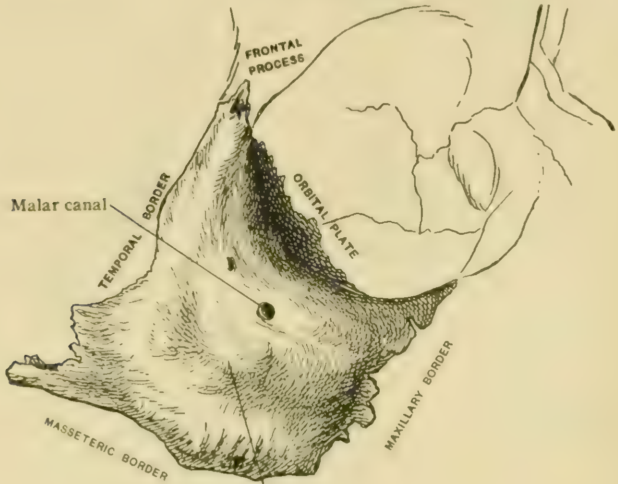
THE MALAR BONE.

This bone[2] forms the prominence of the cheek, the outer border of the orbit, most of the wall separating the orbit from the temporal fossa, and completes the zygomatic arch. For simplicity of description it is best to consider it a diamond-shaped bone, with an outer and an inner surface, four angles, four borders, and one important process, the orbital, which is neither an angle nor a border. The *outer surface* presents a slight prominence, the *tuberosity*,[3] a little below the middle. The surface is nearly smooth, except that near the lower border there is often a certain roughness extending onto the zygomatic process for the origin of the masseter muscle. The greater part of the *inner surface* is smooth, looking towards the temporal and zygomatic fossæ ; but a rough space under the front angle joins the malar process of the maxilla. It sometimes helps to close the antrum, in which case a part of it is smooth, being lined with mucous membrane. The superior angle, or *frontal process*,[4] joins by a rough surface the external angular process of the frontal. The posterior angle, or *zygomatic process*,[5] more prominent below than above, joins the zygomatic process of the temporal, passing below it. The anterior and the inferior angles have no special names. The postero-superior, or *temporal border*, is at first vertical, becoming horizontal towards the hind end. Near the beginning there is a posterior projection, the *marginal process*, which varies considerably. The postero-inferior, or *masseteric border*, slightly irregular, is free, forming the lower edge of the front of the zygoma. The antero-inferior, or *maxillary border*, is slightly concave. It articu-

[1] Ossa nasalia. [2] Os zygomaticum. [3] Tuberositas malaris. [4] Processus frontosphenoidalis. [5] Processus temporalis.

lates with the front of the malar process of the maxilla, bounding externally the rough surface of the inner side of the malar. The antero-superior, or *orbital border*, is smooth and concave, forming the external and most of the inferior boundary of the orbit. The *orbital plate*, or *process*, which forms the front of the outer wall of the orbit, projects inward from this border, joining the bone at nearly a right angle.

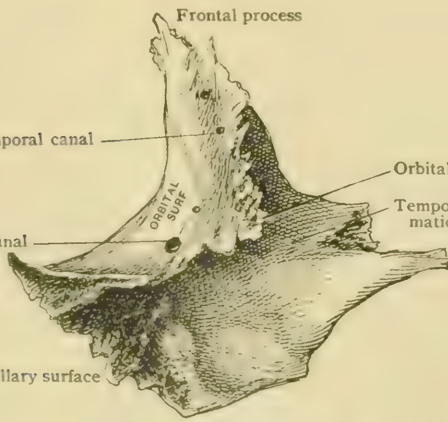
FIG. 239.



Right malar bone, outer aspect.

It is narrow in front and broad behind, where its anterior surface looks towards the orbit and its posterior towards the temporal fossa. Its projecting edge is jagged throughout, and in front meets the superior maxilla. Behind that it joins the outer border of the great wing of the sphenoid, and above articulates with the frontal. Between the part meeting the maxilla and that meeting the great wing there is usually a short, smooth surface bounding the end of the spheno-maxillary fissure, which lies between these bones in the lower outer angle of the orbit. Two *foramina* on the orbital surface lead to minute canals. The lower, the *malar*,[1] opens on the outer surface of the bone; the upper, the *temporal*,[2] opens on the back of the orbital process. They transmit branches from the superior maxillary division of the fifth nerve. They vary greatly.

FIG. 240.



Right malar bone, inner aspect.

In all mammals the primary function of the malar is to unite the maxilla and the temporal bone. Its union with the frontal is a further development. Only in primates does it join the sphenoid and separate the orbit from the temporal fossa.

Articulations.—The malar bone articulates with the frontal, superior maxillary, temporal, and sphenoid bones.

Development and Variations.—There are three centres of ossification—an

[1] Foramen zygomaticofaciale. [2] Foramen zygomaticotemporale.

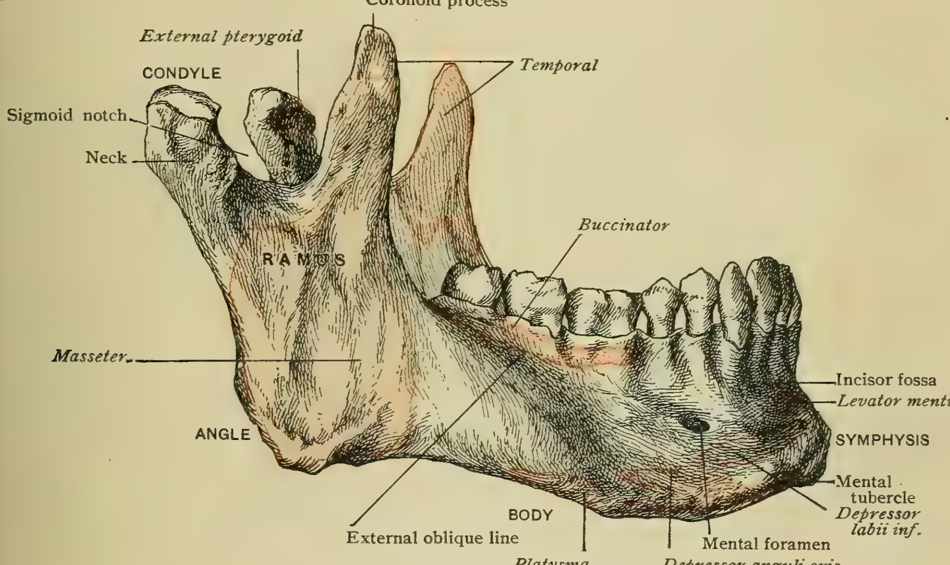
anterior, a posterior, and an inferior—appearing towards the end of the second fœtal month. They fuse in the course of the third. Sometimes, but very rarely in the white races, the bone is divided by a fissure—as in some apes—into an upper and a lower part. This is said to be relatively common (seven per cent.) in the Japanese. A division into three has been seen. The roughness for the masseter sometimes gives a deceptive appearance of a separate piece to this portion. On the other hand, an occasional slight horizontal cleft in the zygomatic process is probably a remnant of a division.

THE INFERIOR MAXILLA.

The inferior maxilla,[1] mandible, or lower jaw develops in two symmetrical halves, which soon fuse. The bone, as a whole, consists of a central part—the *body* —forming the chin and supporting the teeth, and two *rami* projecting upward from the back on either side and articulating with the glenoid fossa of the temporal.

The **body** is convex in front and concave behind. The line of junction of the original halves is the *symphysis*, marked by a slight line. There is a forward projection of the lower border of the chin which is a human characteristic. A short

FIG. 241.



Inferior maxillary bone, outer aspect.

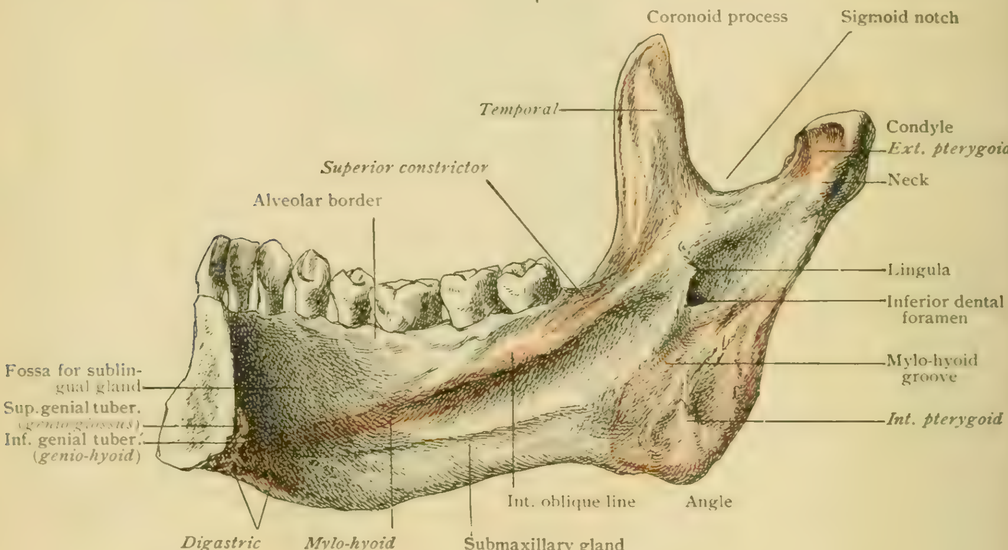
distance from the median line at the lower border is the *mental tubercle*[2] bounding this projection laterally. The *alveolar process*, above the body, is of the same nature as that of the upper jaw. A slight depression, the *incisor fossa*, is found below the teeth of that name on the front of the bone. The *mental foramen* for the terminal branches of the inferior dental nerve and artery is rather below the middle of the bone under the second bicuspid, sometimes just before it. The *external oblique line*,[3] starting from the mental tubercle, passes below the mental foramen into the front edge of the ramus. Sometimes it seems to spring from the lower border under the molar teeth, and sometimes both these origins may be present at once. On the lower border of the bone, rather to its inner side, there is a rough oval behind each mental tubercle for the anterior belly of the digastric muscle. The inner side of the body is in the main smooth. The *superior* and *inferior genial tubercles*[4] are two pairs of small, sharp spines near the lower part of the inner side of the symphysis for the genio-glossi and genio-hyoid muscles respectively. The *internal oblique line* begins at first very indistinctly near the genial tubercles, and is lost on the inner side of the ramus. It is particularly prominent under the molars, and gives attach-

[1] Mandibula. [2] Tuberculum mentale. [3] Linea obliqua. [4] Spinae mentales. [5] Linea mylohyoidea.

ment to the mylo-hyoid, which forms the muscular partition separating the oral cavity from the superficial region under the chin. There is a faint hollow, the *sublingual fossa*, above it, below the incisors, for the sublingual gland lying beneath the mucous membrane, and a deeper one, the *submaxillary fossa*, for the submaxillary gland below the line near the junction of the body and ramus.

The **ramus**, which joins the body at an angle of from 110° to 120° in the adult, is a four-sided plate with an outer and an inner surface. The point of union of the posterior and inferior borders is called the *angle*, and is generally turned outward with a lip, which helps to form the under part of the *masseteric fossa*, on its outer side, for that muscle. When well marked, it represents the fossa which is so striking in the carnivora and some other orders. The fossa is not always present, the muscle being then inserted into a roughness. At the front of this space the lower border of the bone is often grooved by the facial artery crossing it. A projection, known as the *lemurine process*, may extend from the angle either backward or downward, but is not often large. The lower border of the ramus, where it joins the body, often presents a concavity, which is sometimes very marked, giving a peculiar outline ; it is named the *antegonium* by Harrison Allen. There is a roughness on the inner side of the ramus at the angle for the internal pterygoid. About on a line with the free edge of the alveolar process is the lowest point of the *inferior dental foramen*,[1] an opening into the *inferior dental canal* for the nerve and artery to the teeth ; the foramen is guarded in front by a sharp point, the *lingula*. A faint groove is continued from this opening below the internal oblique line for the mylohyoid vessels and nerve. The front border of the ramus is thick below and narrow above, where it becomes the *coronoid process*,[2] pointing upward and outward, into which the temporal muscle is inserted. The outer border of the thick part is made by the external oblique line, which is continued into the thin edge above ; the inner border is continued from the inner edge of the alveolar process, or sometimes from the internal oblique line. It ends on the inner surface of the coronoid process. The posterior border of the ramus slants upward, backward, and a little outward. It is rough at the angle and smooth above, where it widens to form the back of the *head* or *condyle*.[3] This presents an articular surface convex from before backward and higher at the middle than at the ends. The longest diameter is not quite transverse, for the axes, if prolonged, would meet near the front of the foramen magnum. There is a pretty distinct tubercle at the outer and inner ends. The condyle has

FIG. 242.



Inferior maxillary bone, inner aspect.

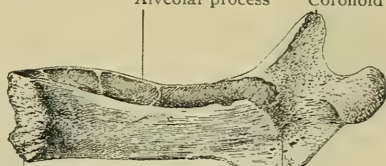
[1] Foramen mandibulare. [2] Processus coronoideus. [3] Capitulum mandibulae.

the appearance of being set rather on the front of the *neck*,[1] which is merely a constriction below the head; the articular surface, however, extends at least as far down behind as in front. There is a depression for a part of the insertion of the external pterygoid on the front of the neck internal to the *sigmoid notch*,[2] which is the deep depression separating the coronoid process from the condyle. The *dental canal*[3] sweeps downward and forward with a slight curve, and then runs

FIG. 243.

Section through body of lower jaw, anterior surface.

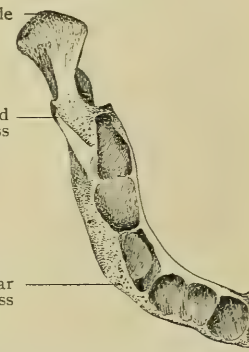
FIG. 244.



Right inferior maxilla at about birth, inner aspect.

horizontally nearer the lower than the upper border of the body of the jaw.[4] It lies at first against the inner wall, but soon is nearer the outer. This relation then varies, but towards the anterior end of its course it is against the inner wall. It divides under the second bicuspid into the *mental canal*, some five millimetres long, running to the mental foramen, and into the *incisive canal*, much smaller, for the vessels and nerves of the front teeth, which, after dividing, is lost in the cancellated tissue under the lateral incisor.

FIG. 245.



Right half of lower jaw at about birth, from above.

Structure.—The jaw is of very tough bone, especially at the symphysis, where it is almost solid. On section the body shows very thick walls below, before, and behind. The alveolar processes, on the contrary, are made of very light plates that are absorbed rapidly after the loss of the teeth.

Development and Growth.—The two halves of the inferior maxilla are formed separately, each from six centres. They are at first connected by ligament. Even before birth the union seems very close, but they become coössified only in the course of the first year. The centres appear from the sixth to the eighth week of fœtal life in the membrane of Meckel's cartilage, except as otherwise mentioned. They fuse during the third month. The centres are: (1) the dentary, which is a line of ossific deposit forming the lower border and the front of the alveolar process; (2) one in the distal end of Meckel's cartilage, for the region of the symphysis; (3) one for the coronoid; (4) one appearing in cartilage, not that of Meckel, for the condyle and top of the ramus; (5) one for the angle; (6) the splenial, for the inner alveolar plate, extending back to include the lingula. This one appears some three weeks later than the others. Still another minute one is said to help to form the mental foramen (Rambaud et Renault). All these, except that for the condyle, which unites at fifteen, fuse shortly after their appearance. The mandible, being at first nothing but a hollow bar to hold tooth-sacs, is very shallow. The ramus is small, the head bent backward and the angle very large. At birth it is about 140°. With the loss of teeth, from whatever cause, the alveolar process atrophies. In old age the bone is very small and of light structure, and the angle enlarges considerably, so as to mimic the infantile form.

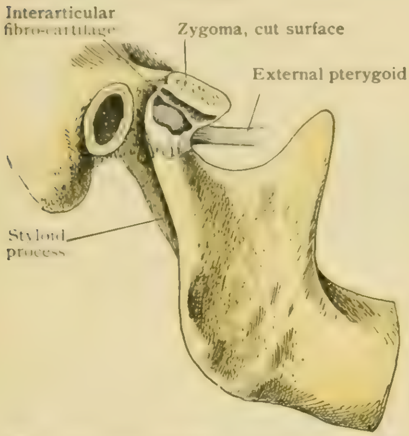
[4] Fawcett: Journal of Anatomy and Physiology, vol. xxix., 1895.

[1] Collum mandibulae. [2] Incisura mandibulae. [3] Canalis mandibulae.

THE TEMPORO-MANDIBULAR ARTICULATION.

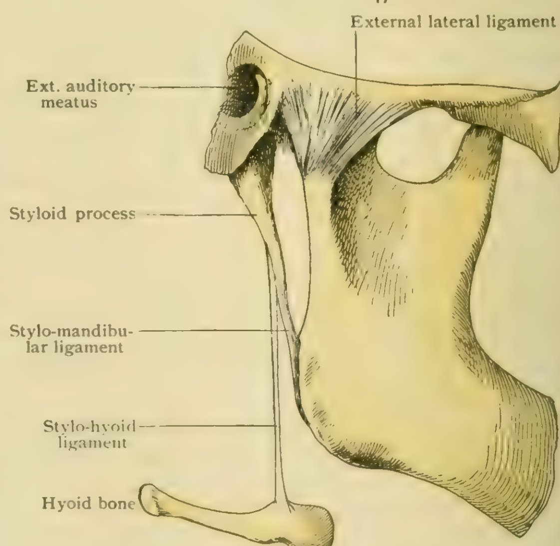
This is a compound joint, the elements of which are the *socket*, the *condyle*, and the *meniscus*, an intra-articular disk of fibro-cartilage, dividing the cavity into an upper and a lower part, both being enclosed by one *capsular membrane*. The *socket* includes the glenoid fossa and the articular eminence of the temporal bone. The articular coating of the socket, which is continued onto the front of the articular eminence, is not true cartilage (Langer), though resembling it to the naked eye. The socket is bounded behind by the fissure of Glaser. The tympanic plate behind it is covered by areolar tissue and a part of the parotid gland, which extend to the back of the head of the jaw and make the socket much narrower and deeper than it seems on the dry bone. The *interarticular fibro-cartilage*[1] is oblong transversely with rounded angles. It rests more on the front of the condyle than on the top. It is concave both above and below, being moulded on the eminentia articularis and on the condyle. It may be merely one millimetre thick in the middle, and is said to be sometimes perforated. The thick posterior border fits into the highest part of the socket. The *capsule*, lax and weak, is attached to the borders of the articular surfaces and to the edges of the interarticular fibro-cartilage. The *external lateral ligament*[2] is a comparatively strong collection of fibres, strengthening the capsule externally. The fibres run downward and backward from the tubercle on the zygoma, at the outer end of the articular eminence, to the outer side of the neck as far as the hind border. The effect of this insertion is to place the transverse axis of rotation of the jaw, not in the head of the mandible, but in the neck. The capsule receives at the front and inner side two bands of fibrous tissue continuous with the dura mater, which passes through the foramen ovale around the third division of the fifth nerve.[3] The *spheno-mandibular ligament*,[4] formerly improperly called the internal lateral, is a weak fibrous structure originally developed around a part of Meckel's cartilage. It runs from the spine of the sphenoid to the lingula without connection with the joint. The capsule is far too loose to hold the jaw firmly in place, hence it is supplemented by the powerful muscles of mastication. One of these, the external pterygoid, is inserted into both the head of the lower jaw and the meniscus, which it draws forward, being incorpo-

FIG. 246.



The temporo-mandibular articulation; the joint opened.

FIG. 247.



The temporo-mandibular articulation, outer aspect.

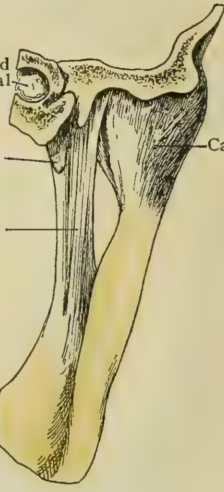
[3] Fawcett : Journal of Anatomy and Physiology, vol. xxvii., 1893.

[1] Discus articularis. [2] Lig. temporomandibulare. [4] Lig. sphenomandibulare.

rated with the front of the capsule. The *stylo-maxillary ligament* is a bundle of fibres of the cervical fascia running from the styloid process to the angle of the jaw.

Movements.—These occur on both sides of the meniscus, which slides forward and backward on the articular eminence. They may be divided into those of opening and closing the mouth and of grinding the teeth. In the former, as the mouth begins to open, the meniscus and the head of the jaw move forward, the condyle at the same time advancing on the former as the lower jaw turns on a transverse axis passing through the neck in both halves of the jaw. This continues as the mouth opens wider, the meniscus descending onto the articular eminence, and probably, when the movement is extreme, rising a little on the other side. This has been graphically demonstrated on the living by an apparatus bearing luminous points at the symphysis, the condyle, and the angle of the jaw, which were photographed as the mouth opened to various widths.[1] It was shown that the forward movement of the meniscus occurs even in a very slight opening of the mouth. The angle of the jaw moves forward at the very beginning of the act, but soon passes backward. The point on it describes some very complex curves. *Grinding movements*, in which the mouth is not opened, must occur chiefly between the skull and the meniscus ; just what occurs below the latter is uncertain. The lower jaw can be thrust forward evenly, as the meniscus of each side descends onto the articular eminence ; but in ordinary motions it seems to advance on one side and perhaps to recede on the other. Spee[2] has shown that the opposed crowns of the molars (and apparently of the premolars also) fall on the arc of a circle that touches the front of the condyle, drawn, when projected on a plane, from a centre on the crest of the lachrymal bone. This allows the teeth of the lower jaw to slide on those of the upper, which the joint would not allow were the line between the teeth a straight one. To this may be added that the inferior incisors rest against the lingual surfaces of the superior, and that the tendency of the edges of the former to make a transverse arch, increased by the wearing away of the outer corners of the lower lateral incisors, implies an alternate rising and falling of either side of the jaw in grinding movements with the mouth closed, though the axis, in the main antero-posterior, cannot be a fixed one. It must be remembered in this connection and in the mechanics of the jaw throughout that the range of variations is great, and that there is frequently a want of symmetry in the joints. This want of precise working is increased by the laxity of the ligaments and the number of muscles acting on various parts of the jaw.

FIG. 248.



The temporo-mandibular articulation from behind.

FIG. 249.

Transverse section of right temporo-mandibular articulation from behind.

Development.—The tympanic portion of the temporal being at birth nothing but the ring, it is evident that the joint belongs solely to the squamous portion, and is always bounded by the fissure of Glaser. At this age the glenoid fossa is nearly flat and the eminentia articularis but slightly raised. Even after birth the joint below the meniscus is very slight, so that but little motion can occur in it, while the meniscus

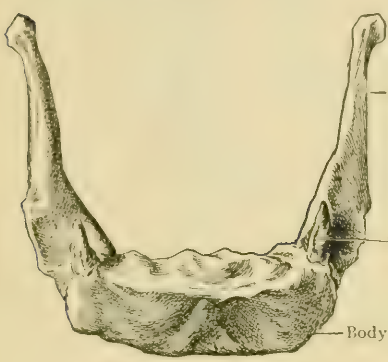
[1] Luce : Boston Medical and Surgical Journal, July 4, 1889.
[2] Arch. für Anat. und Phys., Anat. Abtheil., 1890.

itself can play freely on the flat glenoid. The socket gradually deepens, and assumes something like its definite shape apparently in the course of the third year.

THE HYOID BONE.

This is a U-shaped bone[1] not in contact with any other, situated below the jaw and above the larynx, with which its physiological relation is intimate. It gives origin to a large part of the muscular fibres forming the tongue. It consists of a central *body*, elongated transversely, and of a pair of *greater* and *lesser horns*. The convex anterior surface of the body looks forward and upward; the posterior surface, which is deeply hollowed, faces in the opposite direction. The front surface is divided by a median and a transverse ridge into four spaces, of which the upper are the larger. The *greater cornua* extend with a curve backward and a little upward. They are broadest at their front, and as they pass backward are somewhat twisted, so that the upper surface comes to look outward. Each ends in a small knob. They are connected with the body sometimes by fibro-cartilage, occasionally by a synovial joint. The *lesser cornua*, slender processes some five millimetres long, are the bony terminations of the stylo-hyoid ligaments. There is usually a synovial joint between them and the body, which they join at the ends of the upper border. They may be connected by ligament, and are not very rarely wanting, which simply means that ossification has not occurred at the lower ends of the stylo-hyoid ligaments. The outline of the body and greater horns is easily felt from the surface, and the whole bone can be grasped and moved from side to side.

FIG. 250.



The hyoid bone from in front.

Development.—As embryology shows, the *basihyoid*, or body, is connected with the second visceral arch through the stylo-hyoid ligaments, the lower ends of which become the lesser horns, or *cerato-hyoids*, and with the third arch by the greater horns, the *thyro-hyoids*. The bone ossifies in cartilage, two nuclei appearing (according to Sutton) in the fourth fœtal month, one on each side of the median line, and speedily fusing. A nucleus appears in each greater horn in the fifth month. Statements as to the time of appearance of ossification in the lesser horns vary from a few months after birth to the end of adolescence. The latter is probably nearer the truth. The greater horns rarely coössify with the body before forty-five, but after that age not infrequently. Indeed, in old age they are generally joined. The lesser horns are rarely consolidated before advanced age.

THE SKULL AS A WHOLE.

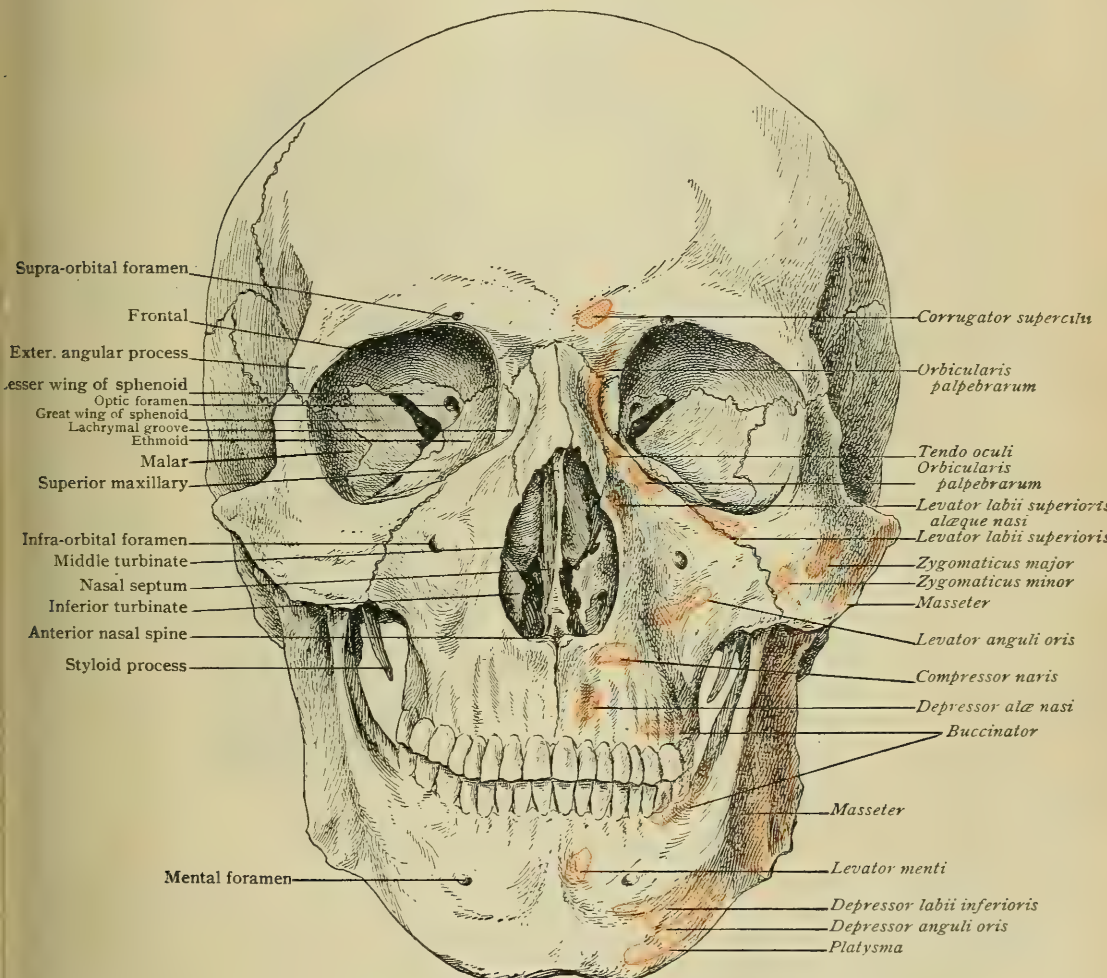
In connection with the description of the skull as a whole, which is not intended to recapitulate the points already mentioned, but to discuss the general features, especially those resulting from the apposition of the distinct parts, let it be remembered that the skull is an egg-shaped structure, and that the face is placed under its anterior and middle fossæ.

The Cranial Sutures.—There are three antero-posterior sutures, a median and a lateral one on each side, and two transverse ones. The median antero-posterior suture is the *sagittal*;[2] it lies between the parietal bones, and is jagged, except at the posterior part, which is usually straight. Occasionally the *metopic suture*[3] persists between the original halves of the frontal bone. It is rarely in direct continuation with the sagittal. The *coronal suture*[4] crosses the top of the head, separating the frontal from the parietals. It ends at the top of the great wing of the

[1] Os hyoideum. [2] Sutura sagittalis. [3] S. frontalis. [4] S. coronalis.

sphenoid below. Its termination is at a vague region where several sutures approach one another, called the *pterion.* In the lower races occasionally, but rarely in the higher, the lower end of the coronal is continuous with the suture between the squamosal and the great wing, in which case two sutures cross each other at right angles, and the pterion is a definite point, an ape-like feature. If the lower corner of the parietal bone is carried downward, and the suture between the great wing and the lower border of the frontal falls considerably, the general plan is that of an H, the cross-piece being the suture between the parietal and the sphenoid; but the H is not often very clear. A separate bone, the *epipteric*, is occasionally found in this

FIG. 251.



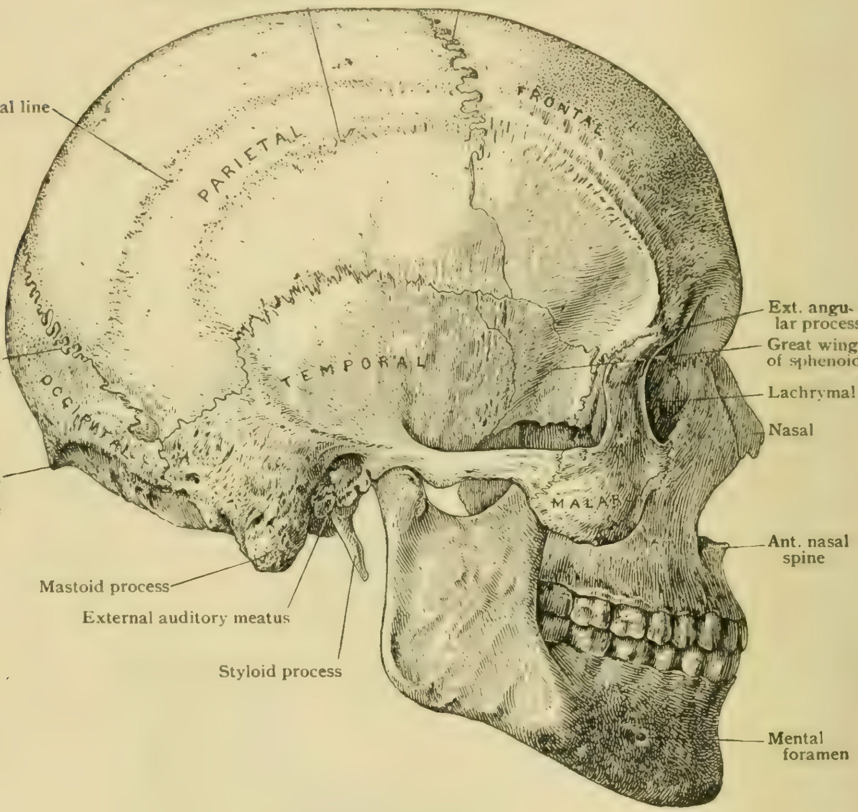
The skull from in front.

region. (See under Growth and Age of the Skull.) The *lambdoidal suture*[1] starts from the top of the mastoid on each side to run upward and backward to a point separating the occipital from the parietals, the interlocking teeth being very long. What is practically a continuation of this suture runs downward between the occipital and the mastoid. Wormian bones are often found, and sometimes in great numbers, in the lambdoidal suture. Sometimes there is a very large triangular one occupying the place of the upper part of the occipital. Such a one may be subdivided. We incline to consider it a Wormian bone rather than a representative of the interparietal

[1] Sutura lambdoidea.

The *lateral antero-posterior suture* begins at the root of the nose and runs through the orbit to the side of the head, ending at the lambdoidal. Its various parts are named from the adjacent bones. Thus, it begins with the *fronto-nasal*, to continue between the frontal and the following bones: the superior maxilla, the lachrymal, the os planum of the ethmoid, the body, the lesser and greater wings of the sphenoid, the malar, and in the temporal fossa the great wing of the sphenoid again. Then behind the coronal it runs between the parietal above and the sphenoid and temporal below.

FIG. 252.



The skull from the side.

THE EXTERIOR OF THE CRANIUM.

Superior Aspect.[1]—This is oval and broader behind than in front, showing the coronal, sagittal, and the top of the lambdoidal sature. On either side is the *parietal eminence*, and in front the smaller *frontal* ones. The superior, and perhaps a little of the inferior, curved lines appear laterally. It is rarely quite symmetrical.

Posterior Aspect.[2]—This is circular in outline, or sometimes five-sided, having an inferior, two lateral (nearly vertical), and two oblique superior borders. Below the middle is the *external occipital protuberance*, which is beneath the most posterior point of the skull.

Lateral Aspect.[3]—This shows nothing of the face that has not been mentioned. The *zygomatic arch* is prominent, bridging over a deep hollow. The part of the hollow above the arch is the *temporal fossa*, deepest in front, and nearly filled by the temporal muscle. The inner wall is formed by the squamosal and the great wing of the sphenoid; the front one chiefly by the orbital plate of the malar. The *infra-temporal crest* on the great wing separates the temporal fossa from the *zygomatic fossa* below. (The latter fossa is described with the face, page 227.) The two *temporal*

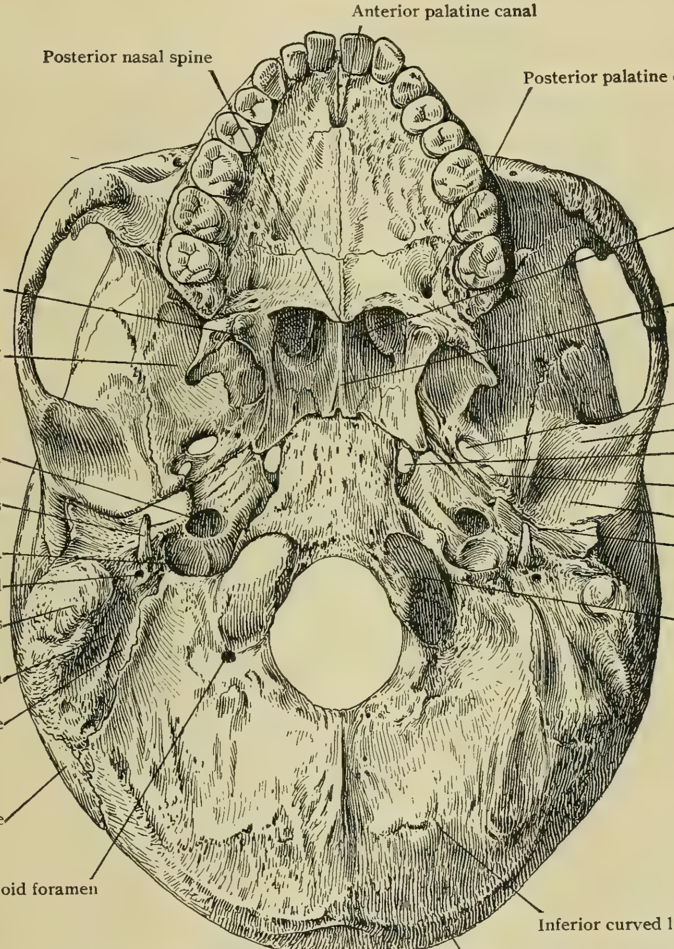
[1] Norma verticalis. [2] Norma occipitalis. [3] Norma lateralis.

lines are to be seen in whole or in part. The inferior always ends in the supramastoid ridge. The mastoid process varies much in development.

Anterior Aspect.[1]—The cranial portion of the skull is seen only above the orbits and the root of the nose. Much of its lower part is occupied by the frontal sinuses.

Inferior Aspect.[2]—(The lower jaw is supposed to be removed.) This aspect may be divided into three regions by two cross-lines, one being at the roots of the pterygoid plates and one at the front edge of the foramen magnum. Passing from behind forward, near the posterior surface, are seen the *external occipital pro-*

FIG. 253.



Base of skull from below, the lower jaw removed.

tuberance and the *superior* and *inferior curved lines.* In front of the latter the occipital bone is convex to the outer side of the foramen magnum. A line connecting the backs of the condyles halves the foramen magnum. The *mastoid processes* appear laterally. Internal to them are the *digastric grooves*, and just internal to these the *occipital grooves*, nearly or quite in the suture. Between the mastoid and styloid processes is the *stylo-mastoid foramen.* The region between the two above-mentioned lines includes the *guttural fossa* in the middle for the pharynx; on each side of this are openings for great vessels and nerves, and, externally, the joint of the jaw. The *basilar process* in front of the foramen magnum forms the

[1] Norma frontalis. [2] Norma basalis.

roof of the pharynx. On either side of it is a rent separating it from the temporal bone. The back of this rent is the *jugular foramen* ; then comes the *fissure* proper ; and, at the apex of the petrous portion, the *middle lacerated foramen*, which in life is filled with cartilage, as is also the fissure. Outside, in the petrous bone, is the *carotid opening*, internal to the tympanic plate, which is separated by the *fissure of Glaser* from the *glenoid fossa*. The outer border of the petrous forms a gutter with the great wing of the sphenoid for the cartilaginous part of the *Eustachian tube*. Just outside of this is the *foramen spinosum*, often in the suture between the sphenoid and temporal, and before it the *foramen ovale*. In the front part of the base outside of the pterygoid is that part of the great wing which looks downward, overhanging the zygomatic fossa.

THE INTERIOR OF THE CRANIUM.

The **vault**[1] of the cranium has the groove for the *superior longitudinal sinus* in the middle, with *Pacchionian depressions* on each side of it. The *grooves* for the middle meningeal artery cover the parietal region. The **base** of the cranium is divided into three fossæ,—the *anterior*, the *middle*, and the *posterior*.

The **anterior fossa**[2] is bounded behind by the line in front of the olivary eminence and by the edge of the lesser wings of the sphenoid. It has a deep hollow over the nasal cavity, the floor of the depression being the *cribriform plate* of the ethmoid. In the median line are the crista galli and the foramen cæcum. The lateral part of the anterior fossa slants downward, inward, and backward, and is quite smooth in the middle behind the hollow.

The **middle fossa**[3] is limited in the centre to the *sella turcica*, but expands at the sides. It is separated from the posterior fossa by the *dorsum sellæ* and the superior border of the petrous. The middle fossa has the *olivary eminence* and the *optic foramina* in front of the sella turcica, at each side of which is the *groove* for the internal carotid artery and the cavernous sinus. The *clinoid processes* tend to meet above its sides, and sometimes do so, especially when the middle clinoid is developed. On the anterior border of the fossa, near the middle, is the *sphenoidal fissure* opening into the orbit. Just behind its inner end is the *foramen rotundum* ; farther back and outward are the *foramen ovale* and *foramen spinosum*, from which latter start the grooves of the middle meningeal artery ; more internal lies the *middle lacerated foramen*. The depression for the *Gasserian ganglion* is seen at the apex of the anterior surface of the petrous portion of the temporal bone ; the ganglion is very conveniently placed for its ophthalmic, superior maxillary, and mandibular branches to reach the sphenoidal fissure, the foramen rotundum, and the foramen ovale respectively.

The **posterior fossa**[4] is much the larger. In the middle is the *foramen magnum*, with the *basilar groove* before it. The impression for the *superior petrosal sinus* is at the top of the petrous. The *inferior petrosal sinus* lies on the suture between the petrous bone and basilar process. The *internal auditory meatus*, the *jugular foramen*, and the *anterior condyloid foramen* are very nearly in a vertical line. The impressions for the *lateral sinuses* run outward from the internal occipital protuberance until they suddenly turn downward, making a deep groove in the temporal bone. The course of the second portion of the sinus is straight downward and inward, the highest point of the sinus corresponding with the supramastoid crest above the middle of the mastoid process. This point is sometimes so near to the surface that the bone is translucent. In its descent the sinus may for a time keep near the surface, or leave it at once. There is much variation in many respects ; sometimes the downward turn of the sinus is less sharp. The claim that anything can be predicated of this from the shape of the head is extremely uncertain. Just before reaching the jugular foramen the sinus once more changes its direction, running forward and upward.

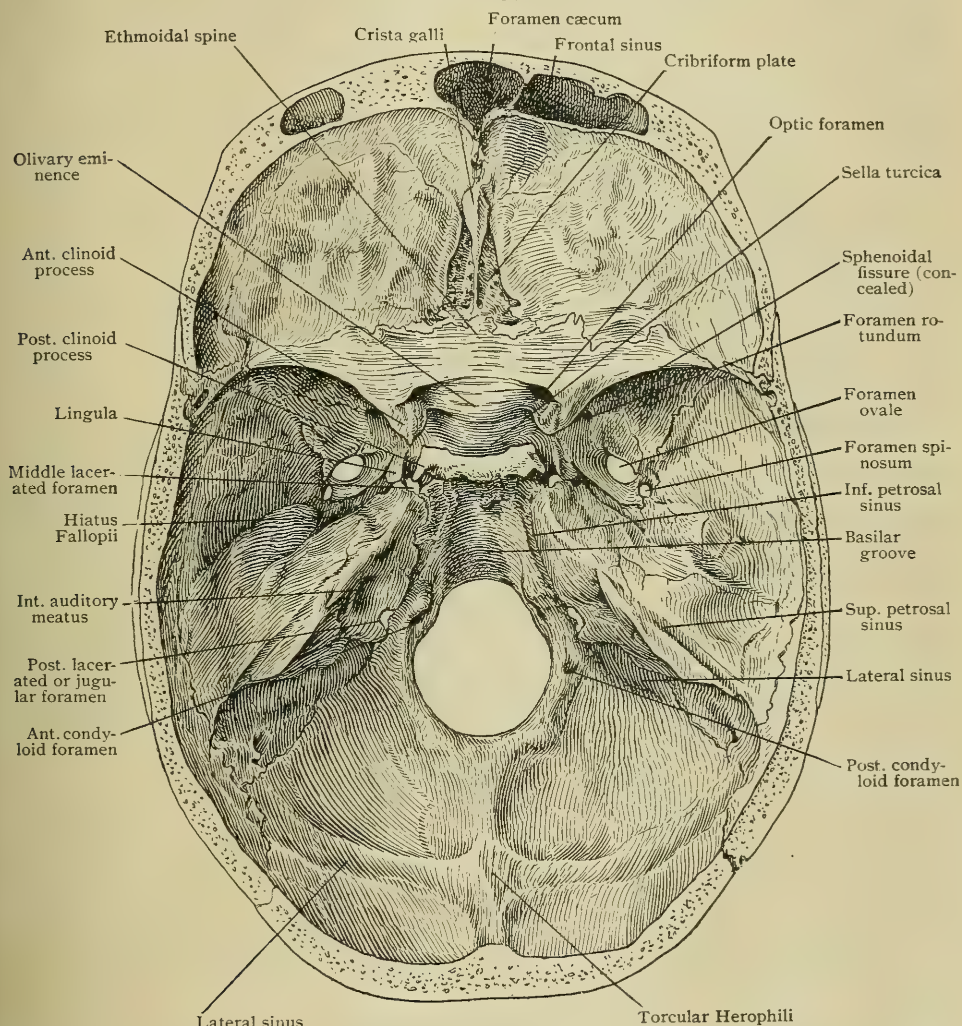
THE ARCHITECTURE OF THE CRANIUM.

The curved vault of the skull is well adapted to break shocks, but the base is much weaker ; not only is the bone thin in many places, but it is interrupted by

[1] Calvaria. [2] Fossa cranii anterior. [3] F. cranii media. [4] F. cranii posterior.

many openings. The whole of the anterior fossa is very thin ; so is the sella turcica, being just over the sphenoidal sinus. A chain of openings crosses the middle fossa on either side. The temporal bone is practically crossed by the external and internal meatuses and the middle ear, besides containing other cavities. Thus the petrous is brittle, although the bone is very dense. A rim of comparatively firm bone extends around two-thirds of the skull, starting on each side from the occipital protuberance, which may be even two centimetres in thickness, along the line of the lateral sinus to the supramastoid ridge ; it follows the line of origin of the zygoma,

FIG. 254.



Base of skull from above.

and ends in the infratemporal crest on the great wing of the sphenoid. A median ridge strengthens the skull in both the frontal and occipital regions. The average thickness of the vault is about four millimetres. It is thick throughout the frontal region and at the parietal eminences, a thin area lying behind and below the latter. The Pacchionian depressions may almost perforate the skull. It is very thin in the squamous part of the temporal ; less so in the superior occipital fossæ.

If the base of a skull be held to the light and examined from within, the

translucency of the following parts will be very evident : the roofs of the orbits, one or two uncertain points in the great wing of the sphenoid, one in the lower part of the squamous portion just outside of the petro-squamous suture corresponding to the glenoid fossa, the beginning of the basilar process, a varying portion of the descending part of the groove for the lateral sinus, and nearly the whole of the floor of the cerebellar fossa. A little rim of firm bone surrounds the foramen magnum except in front.

THE FACE.

This consists essentially of the framework of the jaws and of the orbital and nasal cavities, as well as of certain accessory regions, the *zygomatic* and *spheno-maxillary fossæ.* Apart from features in the bones already described, the front view shows the outline of the orbits, of the nasal opening, of the prominence of the cheek, and of a vacant space left between the upper jaw and the ramus of the lower. The foramina for the escape of the terminal branches of the three divisions of the fifth nerve are very nearly in a vertical line, only the *mental foramen* is usually a little lateral. The side view shows the *zygomatic fossa* below the arch and within the ramus.

The Orbit.—Although the base is quadrilateral, the orbital cavity is conical rather than pyramidal, since its section a little behind the base is almost circular. The *upper margin* of the entrance is formed by the frontal bone, which slants downward to the very prominent *external angular process*, which affords great protection to the eye. The suture with the malar can easily be felt in life, owing to the greater projection of the upper bone. The *outer border* and the inner half of the lower are made by the malar, which has a sharp orbital edge throughout. This is continued by an ascending sharp edge of the superior maxillary into the front border of the lachrymal canal, at the top of which it becomes indistinct. This is to be considered the *inner boundary ;* but there is difficulty in accurately determining this border, for if the upper border be followed down at the inner side, it will be seen to run to the posterior edge of the lachrymal groove made by the ridge in the lachrymal bone. In some skulls this is much the more evident border. The upper part of the inner border is the only one that cannot easily be felt in life. The *roof* of the orbit is arched from side to side and from before backward. It is overhung by the border, especially at the outer angle, where it lodges the lachrymal gland. The *inner wall*, composed of part of the ascending process of the maxilla, the lachrymal, the os planum of the ethmoid, and part of the body of the sphenoid, is nearly vertical in front, but farther back slants inward. The inner wall is frequently quite convex in the middle ; if this condition is marked, it is probably pathological. There is an approach to an angle between this surface and the upper. The two *ethmoidal foramina* are found above the os planum. The inner wall curves gradually into the inferior surface, formed by the maxilla, and presenting the *infra-orbital groove* and *canal.* The *outer wall* slants strongly inward, its lower border being internal to the upper. It is formed by the malar bone in front and the great wing of the sphenoid behind. The back part of the upper angle of the outer wall is occupied by the *sphenoidal fissure*, which opens into the middle fossa of the skull, and the lower angle by the *spheno-maxillary fissure*, separating the wing of the sphenoid from the maxilla ; the outer end of this fissure, closed by the malar bone, opens into the zygomatic fossa. The *optic foramen* is at the posterior point of junction of the roof and the inner wall. The *apex* of the orbit is at the inner end of the sphenoidal fissure.

The **axes** of the orbits, if prolonged, cross each other at the back of the sella turcica at an angle of from 42° to 44°. The orbital axis is, therefore, very different from the visual axis, which is antero-posterior. The former, moreover, runs downward from the apex to the base, making an angle of from 15° to 20° with the horizontal plane.

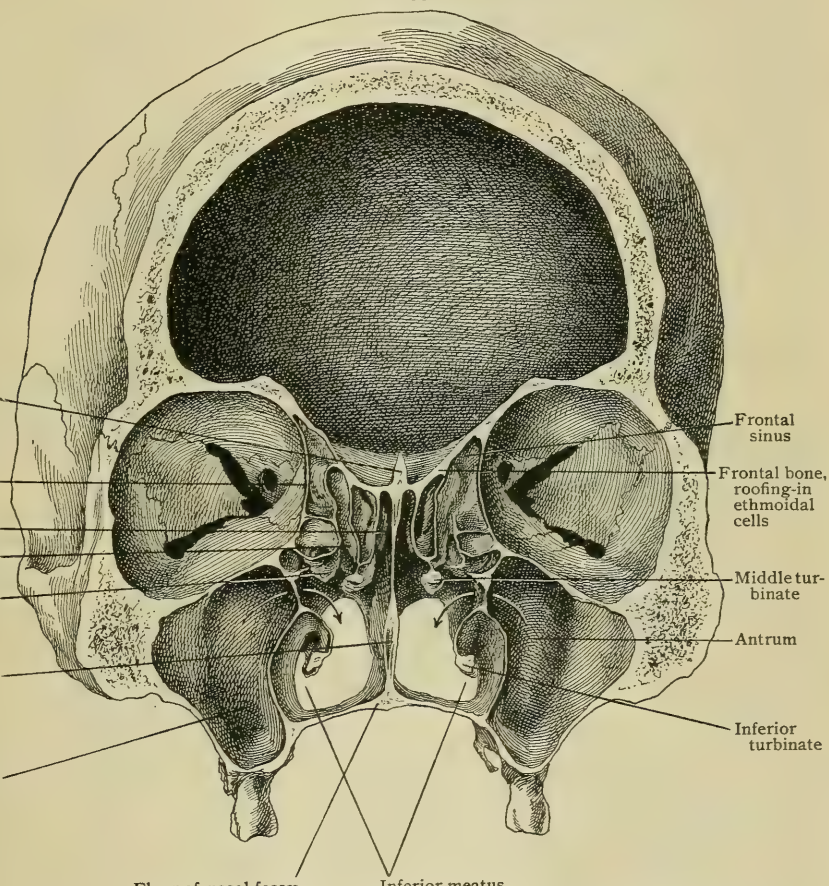
The **dimensions** of the adult orbit vary with different observers and, no doubt, in different localities. The depth is from forty to forty-five millimetres, the breadth at the base is about forty millimetres, and the height about thirty-five millimetres in males. In females the dimensions are rather less.

The roof is thin and separates the orbit from the cranial cavity, except in

front, at the inner side, where the frontal sinus intervenes. This sinus extends downward, mesially, almost to the top of the lachrymal groove. The inner and lower walls, separating the orbit from the nasal cavity and the antrum respectively, are very thin and offer little resistance to a tumor or a foreign body. The great wing of the sphenoid in the outer wall is thick, except just at the edge of the sphenoidal fissure; it separates the orbit from the middle cranial fossa. The outer wall just behind the anterior border is thin, where it cuts off union with the temporal fossa.

The Nasal Cavity.—The nasal cavity of each side has an anterior and a posterior opening, a roof, a floor, an outer wall, and an inner, the *septum*, which, when

FIG. 255.



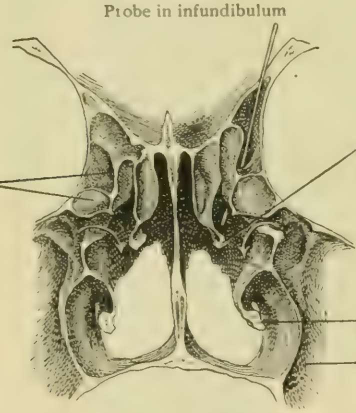
Front section of skull through plane of outer border of orbits. Arrows pass through communication between antrum and middle meatus.

the cartilage is present, completely separates it from its fellow. The **anterior common opening** of the two cavities is shaped like an inverted ace of hearts, bounded above by the border of the nasal bones and elsewhere by the superior maxillæ. In the middle of the floor of the opening is the *anterior nasal spine*, resembling closely the bow of a boat. The anterior edge where the two bones meet is the cutwater, and above is a triangular surface, the deck, bounded by a sharp line, which runs outward, forming the lower border of the opening. In the adult this line is usually continuous with the lateral border of the opening, but in infants' skulls the line passes from the side onto the anterior surface of the maxillary bone. Another line a little behind this, starting inside the nose at the front of the inferior turbinate crest, runs close to the line from the spine. Though these lines are usually

fused in the adult, forming a rather dull inferior border continuous with the lateral sharp one, they may remain distinct and enclose a well-marked fossa on the face just below the nasal opening ; this is the *fossa prænasalis*, rarely seen in other than low races. Variations in the arrangement of these lines may occur, and according to Zuckerkandl,[1] the line from the border of the nose may not always form the anterior border of the fossa. The combined nasal openings, though in the main triangular, may be roughly quadrilateral. More or less asymmetry is the rule. The nasal bones and the nasal spine may point sideways, but not necessarily to the same side. The spine points to the side on which the opening is the wider ; the broader aperture usually does not descend so low as the narrower one. The tip of the nose is more often turned to the right. In life the shape of the nose depends quite as much on the soft parts as on the bones.

The **posterior openings** of the nares, the *choanæ*, are remarkably symmetrical ; bounded above by the wings of the vomer, which conceal the body of the sphenoid, on the sides by the internal pterygoid plates, internally by the vomer, and below by the horizontal plate of the palate, each is much higher than broad. The index of the choanæ, showing the proportion of the breadth to the height $\left(\frac{100 \times \text{breadth}}{\text{height}}\right)$, is 60 for men and 64 for women, showing relatively lower openings in the latter (Escat). Measuring the combined breadth from one pterygoid process to the other at the hard palate on ten adult skulls irrespective of sex, we found the average breadth 27.7 centimetres and the average height 28.4 centimetres. The extremes were 24 and 31 centimetres for the breadth and 25 and 31 for the height.[2] The inclination of the posterior border of the vomer is in a general direct ratio to the degree of prognathism,[3] or the forward projection of the face.

FIG. 256.



Portion of anterior section of preceding skull, seen from behind. The arrows occupy the opening from the antrum into the hiatus semilunaris.

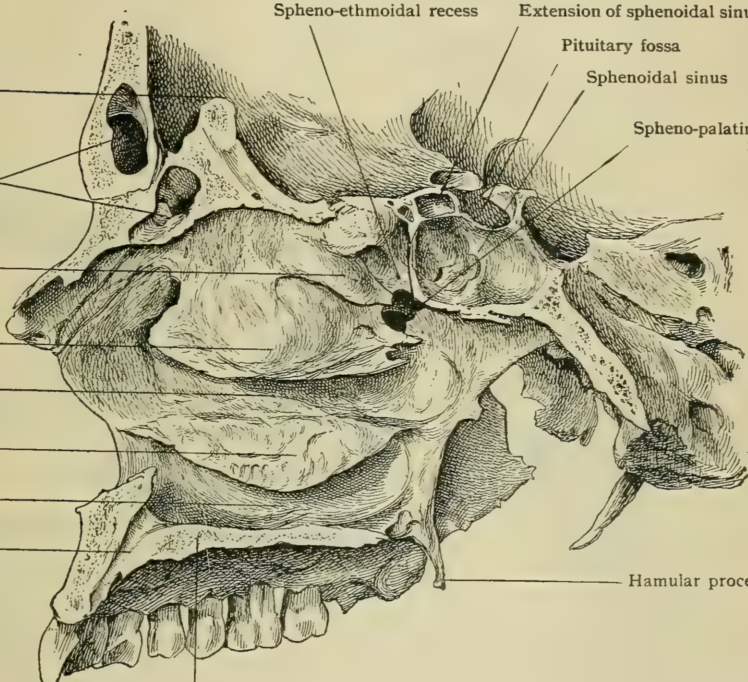
Each **nasal chamber** (Figs. 255, 256) is very narrow, and much higher in the middle than at either orifice. The front part, the *vestibule*, extends under the bridge of the nose. The *roof* is extremely narrow except at the posterior end. It is composed of the nasal bones, thin below, thick above ; of a small part of the frontal, a thin plate separating it from the frontal sinus ; the very thin cribriform plate, easily broken ; the vertical anterior surface of the sphenoid, pierced by an opening into the sinus ; and, finally, the wing of the vomer. The *floor* is a smooth gutter, formed by the palatal processes of the maxillæ and palate bones. The lower border of the anterior nasal opening is higher than the floor, so that an instrument has to be tilted over it.

The *anterior palatine canal* opens through the floor near the front on either side of the septum. The floor, except at the posterior part, is of strong bone, and is smooth all over. The *median wall* is derived from a plate of cartilage, developed at a very early period, from which the vertical plate of the ethmoid and the vomer are also formed. A large quadrilateral space is left vacant in the macerated skeleton, which in life is filled by the unossified portion of the original plate, known as the *triangular cartilage*. Apparently the process of ossification is excessive along the line of union between the ethmoid and the vomer, since the adult septum is usually bent to one side in its anterior two-thirds, thus making one nasal cavity much smaller

[1] Normale und pathologische Anatomie der Nasenhöhle, 2te Auflage, Vienna, 1893.
[2] The development of the nasal cavity is described with that of the head.
[3] Escat : Cavité Naso-Pharyngiene, Paris, 1894.

than the other. A ridge is often found at or near the junction of these two bones on the prominent side, thereby still further reducing the smaller cavity. This ridge may be developed into a shelf, called a spur, which may even touch the opposite wall. The *outer wall* is the most instructive, as giving the most light on the construction of the region. In front is the smooth-walled vestibule, formed by the inner side of the nasal and the ascending process of the maxilla, extending upward under the frontal sinus. The swelling known as the *agger* may be found near the top of its outer wall. The inferior turbinate is much the largest, reaching forward almost to the opening in the bone. The large *inferior meatus* which it overhangs is higher in front than behind. The middle turbinate, over the *middle meatus*, does not extend nearly so far forward. The little superior turbinate with the limited *superior meatus* below it is still farther back, reaching only half-way along the

FIG. 257.



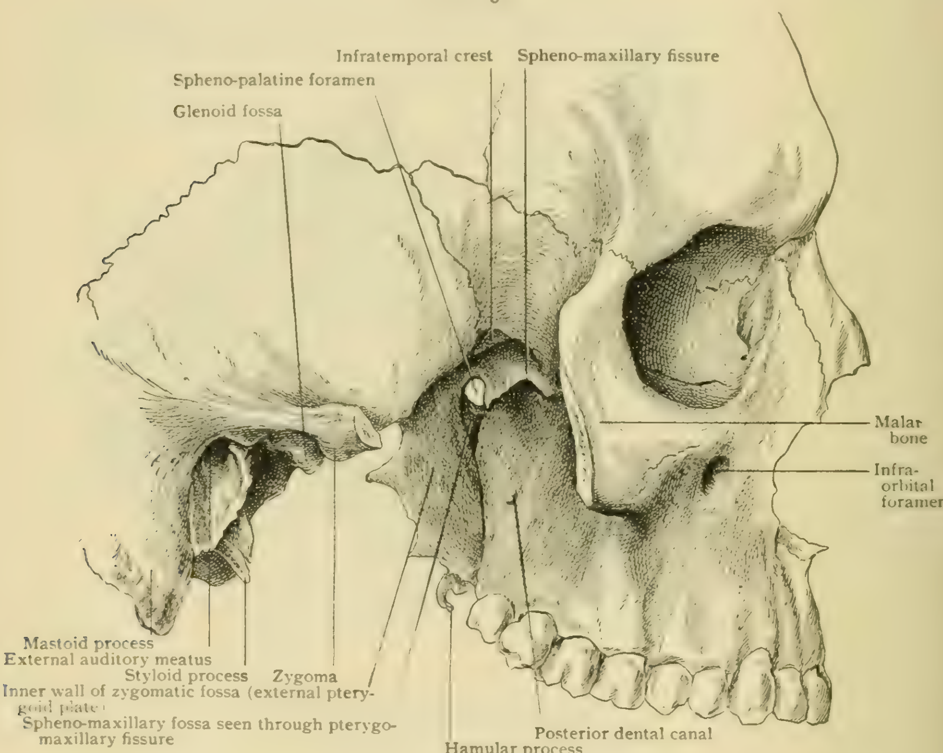
Inner aspect of outer wall of right nasal fossa.

middle turbinate. The three turbinates end behind very nearly in a vertical line, the middle sometimes projecting farthest. The lines of attachment of the turbinates all slant downward and backward, but the inclination of the middle one is greatest. The variations in number of the turbinates and the structures concealed by the middle one have been described with the ethmoid. The *spheno-ethmoidal recess* is a lateral expansion of the cavity behind the superior turbinate and the front of the body of the sphenoid. The posterior portion of the outer wall of the nasal chamber, formed by the palate bone and the internal pterygoid plate, is smooth. The outer wall slants inward, so that the roof of the nasal cavity is narrower than the floor, and has the following openings: in the superior meatus that of the *posterior ethmoidal cells*; farther back is the *spheno-palatine foramen* communicating with the spheno-maxillary fossa. The middle meatus receives the opening of the *frontal sinus* either directly under the front of the middle turbinate or through the *infundibulum.*

These arrangements are about equally common. It receives also the openings of the *anterior ethmoidal cells*, the aperture of the *antrum* into the infundibulum, and a larger opening from the antrum behind the infundibulum. The *lachrymal canal* opens into the inferior meatus under the fore part of the turbinate. External to the outer wall are the orbit, the antrum, and farther back the spheno-maxillary fossa with the posterior palatine canal below it.

The Accessory Pneumatic Cavities.—These include the *frontal sinuses*, the *maxillary antra*, the *ethmoidal cells*, and the *sphenoidal sinuses*. They have already been described with the separate bones, but may be here further briefly considered in their mutual relations to the nasal fossæ and the skull. All of these spaces open into the nasal chambers above the inferior meatus,—the sphenoidal cells into the roof, the posterior ethmoidal cells into the superior meatus, the anterior ethmoidals, the antra, and the frontal sinuses into the middle meatus.

FIG. 258.



Lateral view of skull with zygomatic arch removed.

The **sphenoidal sinuses** (Fig. 257) are almost invariably unequal, the septum being much to one side. The large openings in the front of the body of the sphenoid are much reduced when the cornua sphenoidalia are in place. The openings of the **posterior ethmoidal cells** are small and irregular. The **anterior cells** make a part of the floor of the frontal sinuses. They open either into the infundibulum or under the middle turbinate.

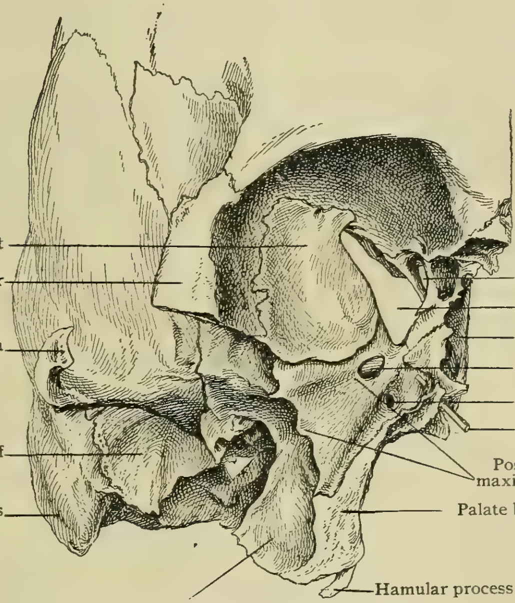
The **frontal sinuses** (Figs. 255, 257), when exposed from the front, have a vaguely triangular outline. One side is against the septum, separating it from its fellow, which is rarely symmetrical. The upper border runs from the top of this downward and outward. The lower border bends downward at the inner end, where the cavity runs down to the nose at the inner angle of the orbit. The inner part extends back for a varying distance over the orbit. In about half the cases the cavity opens directly into the middle meatus; in the rest it opens into the top of

the canal in the ethmoid, known as the *infundibulum*. In the former cases one of the cells of the ethmoid is particularly liable to make a projection—the *frontal bulla*—into the floor of the sinus.

The **antrum** (Fig. 255) is a four-sided pyramid with an irregular base towards the nasal cavity (Merkel). The apex is at the malar. In addition to the base, an orbital, an anterior, and a posterior surface are recognized. Owing to the irregularity of the base there is a groove instead of an angle below, above the alveolar process. (This relation is described with the upper jaw.) The large internal aperture in the superior maxilla is divided into two when the other bones are in place. Both are near the top; the anterior opens into the infundibulum, the posterior into the middle meatus. Partial septa project into the antral cavity. An important projection is that of the infra-orbital canal.

The **zygomatic fossa** (Fig. 258) is the space internal to the lower jaw, separated from the temporal fossa by an imaginary plane at the level of the upper border of the zygoma. It is open below and behind. The front wall is made by

FIG. 259.



Portion of right half of skull, showing posterior wall of spheno-maxillary fossa. The superior maxilla, ethmoid, and part of malar have been removed.

the maxilla, what little roof there is by that part of the great wing of the sphenoid internal to the infratemporal crest, and the inner wall by the external pterygoid plate. It has two important fissures,—the *spheno-maxillary*, horizontal, admitting to the orbit, between the sphenoid and maxilla; the other, the *pterygo-maxillary*, vertical, between the maxillary bone and the front of the united pterygoid plates.

The **spheno-maxillary fossa** (Fig. 259) is a small cavity below and behind the apex of the orbit at the point of junction of the spheno-maxillary and the pterygo-maxillary fissures. The posterior wall is formed by the sphenoid above the roots of the pterygoid plates. The transverse and antero-posterior diameters of the fossa are about fifteen millimetres. It contains the spheno-palatine or Meckel's ganglion. The *foramen rotundum* opens into it behind, transmitting the superior maxillary division of the trifacial nerve. More internal and lower on the posterior wall is the orifice of the *Vidian canal*, transmitting the great superficial and deep petrosal nerves and accompanying blood-vessels. Still nearer the median line is

the minute *pterygo-palatine canal*, formed by the palate and sphenoid bones. The *spheno-palatine foramen* opens through the inner wall into the nasal cavity. The fossa opens below into the *posterior palatine canal*.

The Roof of the Mouth.—This comprises the *hard palate* and the inner aspect of the *alveolar process*. The proportions, as stated elsewhere (page 229), vary; as a rule, the broad palate is less vaulted than the narrow one. The oral roof presents the orifices of three canals,—the *anterior*[1] and the two *posterior palatine*. The first is situated in the mid-line in front, the others at the outer posterior angles. The *palatine grooves* for the anterior palatine nerves and accompanying blood-vessels extend forward from the posterior palatine foramina. Behind, but close to, the latter are the orifices of the accessory palatine canals. The inner side of the alveolar process is rough except opposite the second and third molar teeth, and the same is true of that part of the palate made by the superior maxillæ. An occasional swelling, the *torus palatinus*, is in the mid-line at the junction of the superior maxillæ. Internal to the first molar is a ridge with the groove outside of it at the lateral border of the maxilla. The line separating the superior maxillæ from the horizontal plates of the palate bones has a forward curve in the middle in nearly three-quarters of the cases. It is about straight in some twenty per cent. and curved backward in the rest. The fissures are not always symmetrical.[2]

The Architecture of the Face.—With the exception of the lower jaw, the structure of the face is extremely light. It is subject to no strain save through that bone, and to some extent through the action of the tongue on the palate; it has, however, to be protected against occasional violence. There are certain strong and strengthening regions. The hard palate is strong throughout, except at the hind part, and especially strong back of the incisors. Some strength is gained by a thickening just outside of the nasal opening above the canine teeth, running up into the ridge in front of the lachrymal groove. The root of the nose is also very thick. The face is considerably strengthened through the malar bone and its connections, especially with the robust external angular process. A little support is probably given to the back of the jaw through the pterygoids.

ANTHROPOLOGY OF THE SKULL.

There are certain terms and measurements which should be known, especially as some of them come into practical use in the surgery of the skull.

Points on the Surface of the Skull.—(See also Fig. 265, page 241.)

Alveolar point, the lowest point in the mid-line of the upper alveolar process.
Asterion, the lower end of the lambdoidal suture; three sutures diverge from it like rays.
Auricular point, the centre of the external auditory meatus.
Basion, the anterior point of the margin of the foramen magnum.
Bregma, the anterior end of the sagittal suture.
Dacryon, the point of contact of the frontal, maxillary, and lachrymal bones.
Glabella, the region above the nose between the superciliary eminences.
Glenoid point, the centre of the glenoid fossa.
Gonion, the outer side of the angle of the lower jaw.
Inion, the external occipital protuberance.
Lambda, the posterior end of the sagittal suture.
Malar point, the most prominent point of that bone.
Mental point, the most anterior point of the symphysis of the lower jaw.
Nasion, the point of contact of the frontal bone with both nasals.
Obelion, the sagittal suture in the region of the parietal foramina.
Occipital point, the most posterior point in the mid-line. (It is above the protuberance.)
Ophryon, the point of intersection of the median line with a line connecting the tops of the orbits.
Opisthion, the posterior point of the margin of the foramen magnum.
Pterion, the region where the frontal, the great wing of the sphenoid, the parietal, and the temporal bones almost meet. (As, in fact, they very rarely do meet, the term is a vague one.)

[1] For the description of this canal, see under Superior Maxilla (page 201).
[2] Stieda: Arch. für Anthropol., 1893.

Stephanion, the region where the curved lines on the temporal bone cross the coronal suture.

Subnasal point, in the median line at the root of the anterior nasal spine.

Indices.—The **cephalic index** is the ratio of the breadth to the length of the skull $\left(\frac{100 \times \text{breadth}}{\text{length}}\right)$. The length is taken from the glabella to the occipital point, and the breadth is the greatest transverse diameter above the supramastoid ridge. A high index means a short skull; a low index, a long one. A skull with an index above 80 is *brachycephalic;* from 75 to 80, *mesaticephalic;* below 75, *dolichocephalic.*

The **index of height** is the ratio of the line from basion to bregma to the length $\left(\frac{100 \times \text{height}}{\text{length}}\right)$. A skull with an index above 75 is *hypsicephalic;* from 70 to 75, *orthocephalic;* below 70, *platycephalic.*

The **facial index** is the ratio of the length to the breadth of the face $\left(\frac{100 \times \text{length}}{\text{breadth}}\right)$. The length is from the nasion to the mental point, and the breadth is the greatest at the zygomatic arches. A high index means a long face. A head with a facial index above 90 is *leptoprosopic;* one with a lower one, *chamæprosopic.* In the absence of the lower jaw the index of the upper face may be taken, which is almost equally valuable. The only difference is that the length is taken from the nasion to the alveolar point, and that an index above 50 is *leptoprosopic*, and one below it *chamæprosopic.*

The **nasal index** is the ratio of the length of the nose to the breadth $\left(\frac{100 \times \text{length}}{\text{breadth}}\right)$. The length is measured in a straight line from the fronto-nasal suture to the anterior nasal spine. A skull is *leptorhine* when the index is below 48; when from 48 to 53, *mesorhine;* and when above 53, *platyrhine.*

The **orbital index** is the ratio of the height of the base to the breadth, thus $\left(\frac{100 \times \text{height}}{\text{breadth}}\right)$. The breadth is a horizontal from the outer border to the point of contact of the frontal with the maxilla and lachrymal. A large index means a high orbit. An orbit with an index below 84 is *microseme;* with one from 84 to 89, *mesoseme;* with one above 89, *megaseme.* An index of 70 is low for a Caucasian, and one of 106 very high. The average for English skulls is said to be 88. The index depends considerably on the extent to which the upper border overhangs.

The **palatal index** is the ratio of the breadth to the length. The former is taken from the socket of the second molar of one side to that of the other; the latter is from the alveolar process in the middle line to the posterior nasal spine $\left(\frac{100 \times \text{breadth}}{\text{length}}\right)$.

Prognathism denotes the forward projection of the face. This was formerly expressed by what is known as *Camper's facial angle*, which was measured on the arc between two lines meeting at the nasal spine, one starting from the auricular point, the other from the most prominent part of the forehead in the middle line (avoiding the projecting nose). This has fallen into disuse owing to inherent defects, and perhaps in part to the discordant directions given for drawing the lines. *Flower's gnathic index* is the ratio of the line from the basion to the alveolar point to the line from the basion to the nasion $\left(\frac{100 \times \text{basi-alveolar line}}{\text{basi-nasal line}}\right)$. A skull is *orthognathous* with an index below 98; *mesognathous* with one from 98 to 103; *prognathous* with one above 103.

Shape of the Skull.—Extreme forms occur in Caucasians. The long, narrow skull, with often a slight prominence along the sagittal suture, the *scaphoid form*, is due to the early closure of the sagittal suture, and the short, round skull to that of the transverse ones. In support of this theory is the fact that the *metopic* or median frontal suture is never found in narrow, but only in broad skulls. The high, sugar-loaf, *acrocephalic* skull shows obliteration of all three sutures on the top of the vault. The great backward occipital projection sometimes seen is usually associated with many Wormian bones in the lambdoidal suture.

The long type of skull is naturally associated with the long, narrow face, and the round head with the broad face; but the connection is not absolute. The two types of face deserve a short consideration. The *narrow face* has the high orbit, the narrow nose, with the aperture pointed above, and a long, narrow palate. The outline of the range of teeth in one jaw to a great extent determines that of the other; but, in addition to the smaller curve, the lower jaw in this form is rather delicate, is particularly likely to show the constriction in front of the masseter, and has a more obtuse angle. The *short* and *broad face* has wide, low orbits, a broad and almost quadrilateral opening of the nose, and a wide pair of jaws, the lower with an approximately square angle. If, as is most probably the case, the head is *orthognathous*, the edges of the teeth tend to form part of an antero-posterior curve, which is particularly marked in the region of the molars. It is to be noted, however, that some, or any, of these features may be found in a face of the opposite type.

Dimensions of the Skull.—The actual length of the various diameters is of much less importance than their relations to one another in the science of craniology; they may, however, be important in medico-legal questions. With the exception of the height, they vary within wide limits, even among Caucasians. In the following table the means of both sexes are from Broca:

Mean.	Males. Millimetres.	Females. Millimetres.
Length	182	174
Breadth	145	135
Height	132	125

Cranial Capacity.—This may vary in all races from 1000 to 1800 cubic centimetres. Welcker gives the following means and extremes for white races:[1]

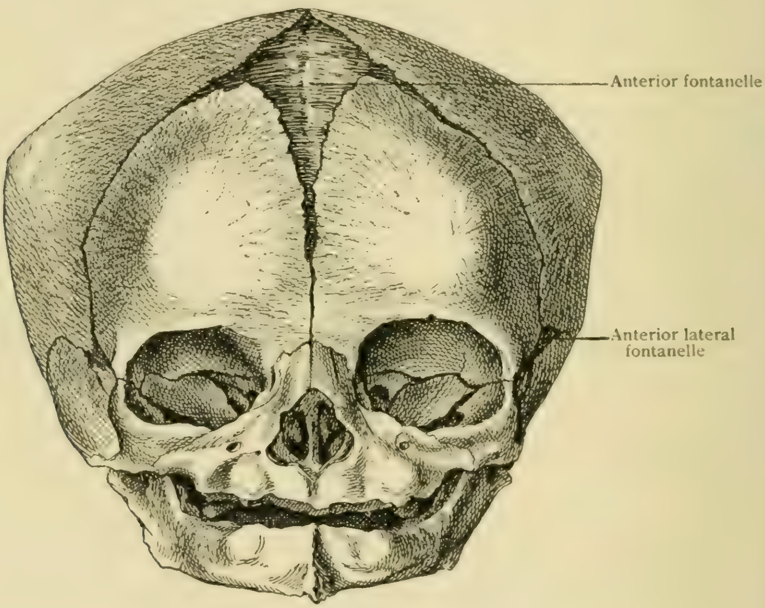
	Mean Cu. cm.	Maximum. Cu. cm.	Minimum. Cu. cm.
Males	1450	1790	1220
Females	1300	1550	1090

A skull with a capacity exceeding 1450 cubic centimetres is *megacephalic;* one with a capacity from 1350 to 1450, *mesocephalic;* one below 1350, *microcephalic.*

Manouvrier has devised a formula for calculating the weight of the brain from the cranial capacity, as follows: weight in grammes is to capacity in cubic centimetres as 1 to 0.87.

Asymmetry.—The whole head is almost always asymmetrical. The left side of the cranium, as shown by hatters' models, is larger, especially in the frontal region. The right side of the head is usually the higher. The cause of this is probably to be found in habitual position. The spine is not held symmetrically, but the atlas inclines to the left; the head, when held most firmly, does not rest evenly on both condyles, but on one, usually the left. The position of the head, thus taken, is not enough to compensate for the obliquity of the base; but certain changes take place in the relations of the component parts. Thus a face which seems

FIG. 260.



The skull at birth, from before.

tolerably symmetrical when resting on the left condyle only becomes quite uneven if placed upon both. The right orbit is usually the higher, the right side of the jaw is the stronger, and its teeth are set in a smaller curve. The tip of the nose turns to the right. Moreover, the face lacks symmetry in another direction: the right upper jaw and the malar bone are more prominent than the left. More striking differences, depending on these, are seen during life, which are ascribed to the effect of gravity on soft parts habitually held unevenly, the right side being the higher. The right eye is the higher and, apparently, the larger, the lids being farther apart; while the cleft is narrow on the left and the eye nearer the nose. The left nostril is the larger; the left fold of the cheek is less marked. In a certain proportion of persons all these peculiarities are reversed, and some of them may be transposed without the others.

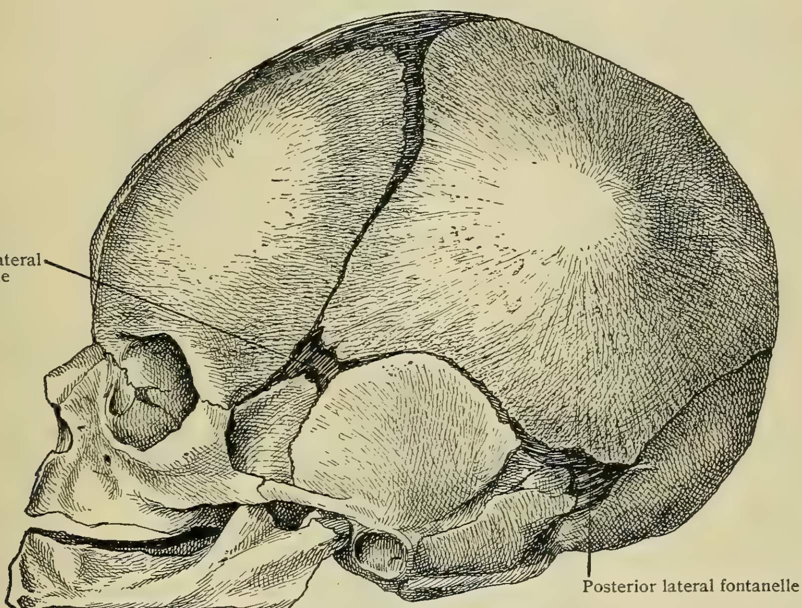
Growth and Age of the Skull.—By the sixth month of fœtal life the skull, though smaller, is in much the same condition as at birth, except that then the occipital region is relatively larger. The most striking points are the insignificance of the face and the flatness of the inferior surface. In the cranium the frontal region is relatively small. The vault, which is developed in membrane, presents marked prominences at the parietal and frontal eminences, and a smaller one at

[1] Extreme cases occasionally pass these limits. There is in the Warren Museum the skull of a Highlander with a capacity of 1990 cubic centimetres, and one of a tall man, presumably an American, who could read and write, though his intelligence was defective, with a capacity of 1225 cubic centimetres. Turner has noted the skull of a female Australian of 930 cubic centimetres' capacity.

the external occipital protuberance, from which radiating lines in the bone mark the process of development. The bones of the vault are exceedingly thin. Each is separate, the external periosteum and the dura uniting at the edges, thus limiting the spread of an effusion under the former to one bone.

Six places where there are considerable membranous intervals between the developing bones are called **fontanelles.** They are situated at the four angles of the parietal bones, so that two are median and two are on either side. The median ones, by far the most prominent, are the anterior and posterior fontanelles. The *anterior fontanelle*, an important landmark in midwifery, is a diamond-shaped space between the rounded angles of the parietals and frontals, some thirty-five millimetres long by twenty-five millimetres broad. This one continues to grow after birth, and is not closed till some time in the first half of the second year, or even later. The *posterior fontanelle* is situated at the apex of the squamous portion of the occipital, extending between the parietals. At an early stage, owing to the median fissure in the occipital, it is diamond-shaped, but later it is triangular. The space is more or less filled up in the last two months before birth, but it may not be truly closed for a month or two after. The *anterior lateral fontanelle* is a small unimportant space at the lower anterior angle of the parietal, above the great wing of the sphenoid, and extending around it. It usually closes at from two to three months after birth. The part between the sphenoid and squamosal is likely to persist the longest. According to Sutton,[1] in early fœtal life the orbito-sphenoid bone reaches the lateral

FIG. 261.



The skull at birth, lateral aspect.

wall of the skull at this point, and a piece of cartilage belonging to it is found in this fontanelle. It becomes bone in the course of the first year, and may unite with either sphenoid, temporal, frontal, or parietal, or persist as the *epipteric bone.* It most often joins the parietal. The *posterior lateral fontanelle*, under the corresponding angle of the parietal, extends down between the temporal and the occipital. It is larger than the preceding, and may be very distinct for a month or more after birth. Its complete closure is said never to occur before the twelfth month, and, perhaps, usually not till the second year.[2] The *sagittal fontanelle* (see Ossification of Parietal) may be present at the seventh month of fœtal life, or later. The oblique fissure at the line of junction of the two parts of the squamous portion of the occipital persists till after birth, and must not be mistaken for an effect of violence.

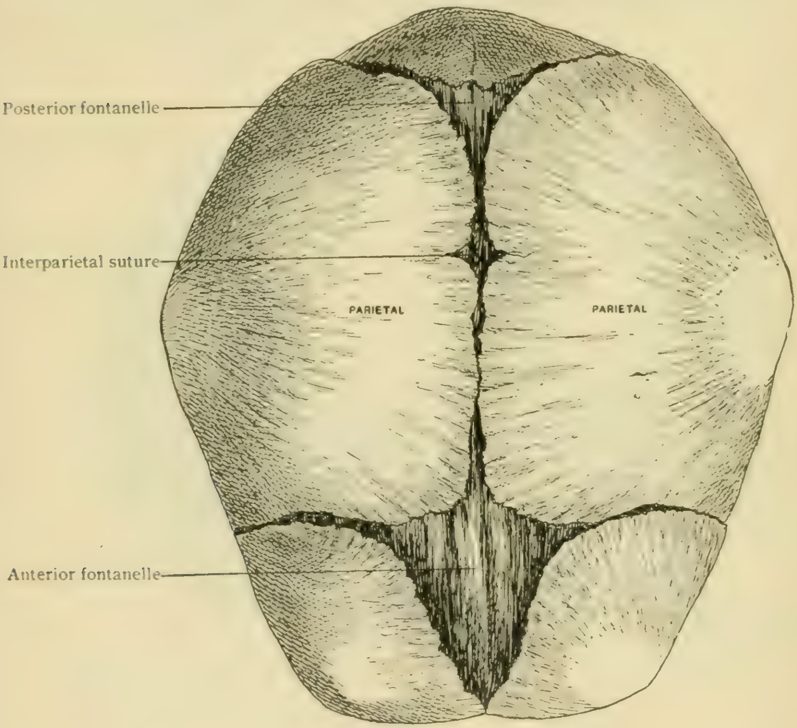
The mastoid process does not exist at birth. The tympanic bone is a mere frame for the ear-drum. The base of the cranium is very flat. The condyles are barely prominent, and the basilar process rises but slightly.

In the first year the outer surface of the bones of the vault becomes smooth. The bones gain in thickness, and in the second year the diploë appears. At the same time the jagged points develop in the sutures, and at the end of that year the metopic suture between the frontals closes.

[1] Journal of Anatomy and Physiology, vol. xviii., 1884.
[2] Adachi: Ueber die Seitenfontanellen, Zeitschrift für Morph. und Anthrop., Bd. ii., Heft 2.

The *face*, while helping to form the orbit and nasal cavities, is essentially for the jaws, and the jaws for the teeth. The greatest change in the head after birth is the downward growth of the face. According to Froriep, in the infant the face is to the cranium as 1 to 8; at two years as 1 to 6; at five, as 1 to 4; at ten, as 1 to 3; in the grown woman as 1 to 2.5; in the man as 1 to 2. On contrasting the front view in the infant and adult, counting as "face" all below a line at the top of the orbits and as "cranium" all above it, it will be seen that in the infant the cranium forms about one-half and in the adult much less. The lower border of the nasal opening is at birth but very little below the orbit. A line connecting the lowest points of the malar bones passes at this age midway between the nasal opening and the border of the alveolar process. At birth the nasal aperture is relatively broad; its lower border is not sharply marked off from the face A line from the nasal spine runs outward to end inside the cavity, and the crest from the outer border is still rudimentary, ending shortly on the front of the face, so that at the outer angle there is no distinct separation between face and nasal cavity.[1] The nasal cavity is shallow, the posterior nares very small. The vomer slants strongly forward. The lower jaw is small and the angle of the ramus very obtuse. The alveolar processes are rudimentary. The breadth of the skull at its widest equals or exceeds the combined height of the

FIG. 262.



The skull at birth, from above.

cranium and face in the infant; in the adult it is but three-quarters of it. The breadth of the face is to its height as 10 to 4 at birth, and about as 9 to 8 in the adult.

Merkel divides the growth of the head into two periods, with an intervening one of rest. The first ends with the seventh year, and is followed by inactivity till puberty, when the second period begins. The *first period* may be subdivided into three stages. In the *first stage*, reaching to the end of the first year, the growth is general, but the face gains on the cranium. At six months the basilar process rises more sharply, which, with the downward growth of the face, has an important effect on the shape of the naso-pharynx. The lower part of the nasal cavity gains particularly. The posterior opening doubles its size in the first six months, to remain stationary till the end of the second year. In the *second stage*, to the end of the fifth year, the vault grows more than the base, assuming a more rounded and finished appearance. The face still gains relatively, but grows more in breadth than in height. In the *third stage*, corresponding roughly to the seventh year, the base grows more and the vault less. The face lengthens considerably, the growth in the nasal chambers being chiefly in the lower part. The head, though small, has lost the infantile aspect. The foramen magnum and the petrous portion of the temporal have reached their full size, and the orbit very nearly. The parietal and frontal eminences are still very prominent. The mastoid is rudimentary. This condition lasts till puberty, when the

[1] Macalister: Journal of Anatomy and Physiology, vol. xxxii., 1898.

second period begins. This is marked by growth in all directions, the gradual rounding off of the eminences of the vault, the progress of the mastoid, the strengthening of ridges, the greater curving of the zygomatic arches, and the increase of the face. This last is due chiefly to the advance of the nose, the gain of the superciliary eminences, and the increase of the lower jaw. The rise of the basilar process increases and the occipital condyles stand out more from the bases at the front edges. These processes are nearly finished in the female by nineteen and in the male one or two years later, though, especially in the latter, they require several years more for their absolute completion. The thickness of the vault is very nearly reached by puberty. At seven the frontal sinus is only as large as a pea. Its development is not completed before the twentieth year. There is no means of knowing whether or not it then entirely ceases.

The *orbit* bears nearly the same proportion to the cranium at all ages; but at birth it equals about one-half of the height of the face, and in the adult rather less than one-third. At birth the axis of the orbit is horizontal. While sometimes the transverse diameter of the base of the orbit is much the larger, this does not seem to be always so. As the face grows the vertical diameter increases rapidly, so that, according to Merkel, at five the base lacks only two or three millimetres of the adult height, which it gains in the next two years. The full breadth is probably not attained before puberty.

The changes in the *nasal cavity* are important as an essential element in the growth of the face. At birth the line of the hard palate, if prolonged back, would strike near the junction of the basilar process and sphenoid; at three it strikes near the middle of the basilar; at six, the front edge of the foramen magnum, which is nearly or quite the condition of the adult. The measurements of the vertical diameter of the choanæ are important from their significance with regard to both the nose and the pharynx. At birth the height is from five to six millimetres (seven millimetres is exceptional) and the breadth of each opening very little greater. At from six months to a year both diameters have doubled, their proportions remaining unchanged. There is little change before the end of the second year, when the height increases more rapidly. Thus they change from circular to oblong openings. It is not till after puberty that the height exceeds the distance between the internal pterygoid plates.

HEIGHT OF POSTERIOR NARES.

Authority.	Age.	Sex.	Millimetres.
Disse	4	male	16
Disse	5	female	11
Escat	5		15
Escat	8		18
Dwight	7 or 8		20
Dwight	7 or 8		21
Dwight	10	female	22
Dwight	11		22
Dwight	14	female	22
Escat	14		20
Dwight	15	male	23
Dwight	16½	female	23
Dwight	17	female	19
Dwight	18	male	29
Dwight	19	male	24
Escat	15 to 18 (9 cases)		25

The Closure of the Sutures.—The occipital bone unites with the basisphenoid at the cerebral aspect about seventeen and on the outside of the skull some three years later. The lower end of the suture between the occipital and the mastoid process is one of the first to close. We have seen it lost in a skull of fourteen, of which the other bones were almost falling apart. No doubt this was exceptionally early. The closure of the great sutures of the vault[1] (to which the term is usually applied) begins on the inside of the skull, probably before thirty, at the lower ends of the coronal and at the back of the sagittal, and spreads irregularly. The process is generally far advanced before it appears on the outside. The closure of the sutures on one side of the head does not necessarily follow the same course on the other. It has usually begun on the outside by forty, although the sutures are still distinct. They probably are nearly or quite obliterated on the inside by fifty-five. The apex of the lambdoidal suture is one of the last points to persist internally. It is impossible to state with accuracy the time at which the sutures disappear on the outside, as this may never occur, and the process throughout is utterly irregular. All may be gone very early or all may be distinct at an advanced age. When the metopic suture fails to close in early childhood it is one of the very last to disappear. It is unsafe from the sutures alone to draw any conclusions as to the age of a skull.

The **weight** of the skull in both sexes is greatest from twenty to forty-five.[2]

The **changes in old age** are essentially atrophic. The most striking is the absorption of the alveolar processes; this, however, may occur prematurely from the loss of teeth. The angle of the lower jaw becomes much more obtuse. The thin parts of the face and of the base

[1] Dwight: The Closure of the Cranial Sutures as a Sign of Age, Boston Medical and Surgical Journal, 1890. Parsons: Anthrop. Institute G. Brit. and Ireland, vol. xxx, 1905.

[2] Gurriere and Massetti: Rivista speriment. di Freniatria e de Med. legale, 1895.

of the skull become still thinner and may be quite absorbed. The thinning of the vault is less marked. Occasionally, in extreme age, symmetrical depressions appear in the upper parts of the parietals behind the vertex. In the latter part of life the frontal sinuses enlarge, as the inner table follows the shrinking brain. In some rare cases the skull grows heavier in old age, owing to an increase in thickness of the inner table.

Differences due to Sex.—There is no marked sexual difference in skulls up to puberty. These characteristics appear during the last stage of growth. They may be summed up by saying that the female skull differs less than the male from that of childhood. The parietal and frontal eminences are more prominent; the superciliary prominences and glabella less marked; the zygomata, mastoid, occipital protuberance, and muscular ridges less developed. The whole structure is lighter. The face is smaller in proportion to the cranium, owing to the lighter jaws. The lower jaw alone is also relatively lighter to the cranium.[1] The frontal and occipital regions are less developed than the parietal. Two points are of especial value,—namely, in the female skull the change of direction from the forehead to the top of the head is more sudden, suggesting a definite angle, while in man the passage is imperceptible; and, secondly, in man a wedge-shaped growth above the front of the condyle is more developed, so as to throw the face higher up. There is no trouble in recognizing a typical skull of either sex; but in many cases the decision is difficult, and sometimes impossible.

Surface Anatomy.—It is convenient for many reasons to settle on what shall be called the normal level of the skull. This should be parallel with the axis of the eye when looking at the horizon. It is expressed by a plane passing through the points above the middle of each external auditory meatus and the lowest points of the anterior border of each orbit. A simple method is to regard the upper border of the zygoma as horizontal, but this is not sufficiently accurate with skulls of low races. The following parts are easily explored by the finger: the whole of the vault as far as the superior occipital line, the occipital protuberance behind, and the superior temporal ridges at the sides. Often the bregma and sometimes the chief sutures can be made out. The possibility of parietal depressions is to be remembered in cases of injury; also that they may be expected to be symmetrical.

The superciliary eminences and the upper borders of the orbits are easily explored. The prominence of the former is likely to imply a large frontal sinus; but the converse is not true, for, especially in the latter part of life, there may be a large sinus with no external indication. The sinus always extends downward to the inner side of the orbit, but its expansion outward and backward is very uncertain. The external angular process protects the outer side of the eye, and one or both temporal ridges can be followed from it. The suture between the process and the malar is easily felt through the skin. A line connecting the most prominent points of the zygomatic arches indicates the depth of the orbits.

The zygoma is easily followed backward to the auricle. By pressing the latter forward, the supramastoid crest can be made out. Just below this is the spina suprameatum, close to the cartilaginous meatus. The outside of the mastoid is easily explored. The course of the lateral sinus is in a curved line with the convexity upward from the external occipital protuberance to the upper part of the mastoid, only the lower part of the sinus touching a straight line between those points. According to Birmingham, the descending part follows roughly the line of the attachment of the ear. There is, however, great variation in its course as to the sharpness of its descent and its relation to the surface of the mastoid. It may be exceedingly close, or in no particular relation to it (Figs. 199, 200, and description of the temporal bone, page 179). The antrum leading to the mastoid cells is just back of the upper part of the meatus, often under a small, smooth surface.

The antrum of Highmore in the superior maxilla extends upward to the floor of the orbit, outward into the malar prominence, downward to just above the line of reflection of the mucous membrane from the lips to the alveolar process, and inward to the line of attachment of the ala of the nose, which is above the canine eminence and marks the separation of the antrum from the nasal cavity.

The variations of the upper end of the infundibulum are of interest. In the cases (about one-half) in which it drains the frontal sinus it is easy for fluid from the latter to run through the infundibulum both into the nasal cavity through the hiatus semilunaris and into the antrum through the opening in its outer side. If the

[1] Gurriere and Massetti: Rivista speriment. di Freniatria e de Med. legale, 1895.

infundibulum ends blindly, there is less likelihood of inflammation spreading from the frontal sinus to the antrum. The nasal bones and their junction with the nasal cartilages are easily recognized. The ramus and body of the lower jaw are to be examined from the outside. The head and coronoid process are felt more easily if the mouth be opened.

PRACTICAL CONSIDERATIONS.

The Cranium.—In the development of the cranium, provision is made for its continuous enlargement, so that it may accommodate the rapidly growing brain. Accordingly, the first rudiment is a membranous capsule, at the base of which cartilage is soon formed, giving support to the overlying portions. Then several centres of ossification appear in various portions of the membrane and grow quickly, so as to protect the cerebral mass, the membrane remaining between these centres still permitting the growth and expansion of the contents. Finally, the separate bones become united, first at their edges, then at their angles, to make the complete unyielding bony cranium.

Arrest of these processes at various stages produces the equally various forms of malformation, only a few of which need be mentioned here. It is to be observed that, as a rule, they affect that part of the cranium that is of membranous origin, the base (developed from cartilage) being much more rarely involved. Turner (quoted by Allen) states that this is because the areas of the different bones are less precisely defined, and because the process of ossification is more liable to disturbance in membrane than in cartilage.

In some cases the whole calvaria may be lacking and represented only by a membrane. Fissures extending from the margins of the bones towards the centres may exist, especially in the frontal and parietal bones, and may be mistaken for fractures. Other irregular gaps filled with membrane may be found, and are generally situated at or near the natural foramina for vessels. The ossification of the bones may be so incomplete as to constitute what is called *aplasia cranii congenita*, a condition in infants due, usually, to maternal cachexia, and characterized by the absence of bone either in localized patches or at points scattered over the entire calvaria.

The non-closure of the sutures, or defective development, may be followed by protrusion of the dura mater, either with or without part of the brain, constituting a *meningocele* if the protrusion consists only of the membranes and cerebro-spinal fluid ; an *encephalocele* if it contains brain ; or a *hydrencephalocele* if the contained brain is distended by an excess of ventricular fluid.

These protrusions, in the order of frequency, occur (*a*) in the occipital region ; (*b*) at the fronto-nasal junction ; (*c*) in the course of the sagittal, lambdoidal, and other sutures ; (*d*) at the anterior or lateral fontanelles, and at the base of the cranium, entering the orbit, nose, or mouth through normal or abnormal openings.

In *hydrocephalus* there are practically always atrophy and thinning of the cranium. "The deformities of hydrocephalus are largely determined by the condition of the sutures at the time of the occurrence of the disease. Fixation at the line of the sagittal suture causes bulging at the forehead and the occiput. Fixation at both the lambdoidal and the sagittal sutures causes vertical bulging at the line of the coronal suture and enormous increase of the ascending portion of the frontal bone. Should the intracranial pressure announce itself prior to the closure of any of the sutures of the vertex, the several bones composing it become widely separated and the fontanelles enormously increased in size" (Allen).

In *microcephalus* there is diminution in the size of the cranium and of its cavity, due to premature ossification of the sutures. The subjects of microcephalus are usually idiotic. The operation of "linear craniotomy," by which a strip of bone is excised on either side of the median line of the cranium, was intended to permit of the expansion of the brain in such cases. It has not established itself in surgical favor. The arrested growth of the skull is thought to be due to the arrested development of the brain, and not *vice versa*. The skulls of idiots, even when not markedly microcephalic, approximate in many ways to those of the lower animals,

and form a distinct type characterized by the proportionate largeness of the facial bones, the contraction of the brain-case, especially in front and above, the upward slant of the occipital bone between the foramen magnum and the occipital crest, the projection backward of the frontal bone between the parietals at the situation of the anterior fontanelle, and by many minor peculiarities.

In spite of these, however, they are easily referred to the human species by the descent of the cranial cavity below the level of the glenoid fossa, the number of the nasal bones, the shape of the jaws, the number and direction of the teeth, etc.

Cretinism is said to be associated with initial deformities of the base pertaining to errors of development and trophic changes in the bones arising from cartilage, especially the basilar process of the occipital and the body of the sphenoid. Accessory to these deviations, and in a measure dependent upon them, are the modified facial proportions and dental irregularity of cretins.

The *Wormian bones*, "detached centres of ossification in the marginal area of growing membrane bones, which they aid in occupying intervening spaces among the bones themselves," have been depressed in injuries of the skull, and have resembled fragments of bone pressing against the meninges. The edge of such a bone has been mistaken for a line of fracture. The most frequent cause of the formation of Wormian bones is the stretching of the membranous envelope of the cranial cavity which occurs in hydrocephalus, assistance in the completion of the cranial cavity being supplied by Wormian bones, which may form in numbers, especially along the sagittal, lambdoidal, and squamous sutures.

The fact that in development the cranial bones touch first and unite first at the points nearest their centres of ossification explains the formation and situation of the fontanelles. The four sides of each parietal bone, for example, become united to the four surrounding bones earlier in the middle than at the four angles. At the latter, therefore, there remain spaces covered with membrane.

The *anterior fontanelle*, at the junction with the frontal of the antero-superior angles of the parietal, is the largest, and is not closed for from one to two years after birth. In rickets its closure is much retarded. Its condition, as to fulness or the reverse, gives a valuable indication in many of the diseases of children. In a state of health, the opening, while still membranous, is level with the cranial bones or is very slightly depressed. Systemic exhaustion, malnutrition, diseases associated with depletion of the vascular system, gastric catarrh, chronic diarrhœa, and marasmus, or simple atrophy, all produce a marked depression of the fontanelle, which in the great majority of cases indicates feeding and stimulation.

A *bruit de souffle* of greater or less intensity, and synchronous with the pulse, is often heard over the anterior fontanelle, and was at one time thought to be characteristic of rickets and of hydrocephalus, but has little diagnostic significance.

The *thickness* of the skull varies in individuals, in the various portions of the skull, and often even in the two halves of the same skull.

Humphry observes that, as he has often found the skull to be thick in idiots, and the several bones to be thickest when the skull is small,—*i.e.*, when the brain is small,—"the term 'thick-headed,' as a synonym for 'stupid,' derives some confirmation from anatomy." Anderson says, however, that the weight of the brain does not seem to have any relation to the thickness of the skull, although this does not affect the truth of the statement that as the brain diminishes with age the skull is apt to thicken, the addition of bone taking place on the interior and giving rise to the irregular surface with close dural adhesions often met with in operations upon the cranium in old persons.

The middle cerebral fossa, the centre of the squamous portion of the temporal, and the middle of the inferior occipital fossæ are the thinnest parts of the skull, varying from 1.75 millimetres to .85 of a millimetre, and in exceptional skulls measuring only .2 millimetre in thickness. This has an important bearing on the location of fractures (page 239). At the parietal eminence, the posterior superior angle of the parietal, the superior angle of the occipital, and especially at the frontal eminences and the occipital protuberance areas of thickening are found; at the latter point the skull may measure fifteen millimetres in thickness (Anderson). The average thickness of the remaining parts of the calvaria is from five to 7.5 millimetres.

In trephining these general facts should be remembered, as should the occasional want of parallelism between the inner and outer tables.

The *shape* of the skull is influenced by race and by disease. The racial peculiarities have sometimes a medico-legal significance, but cannot be described here. (See also page 229.) Pathological asymmetry is caused in many ways.

In *rickets* the head is enlarged, and this enlargement seems greater than it really is on account of the retarded growth of the facial bones. All the fontanelles are larger than usual and close later. The anterior fontanelle is sometimes patent at the end of the third or fourth year.

In *craniotabes* the rhachitic softening of the bones favors absorption under pressure. Consequently the regions most affected by the thinning of the bones are the occipital and the posterior half of the parietal, which are between two forces,—the expanding and growing brain within and the supporting surface, as the pillow, without. Various peculiar shapes may result.

The changes in hydrocephalic and microcephalic skulls have already been described.

Syphilis in the young affects especially the fronto-parietal region, producing thickening or nodes of those bones in the vicinity of the anterior fontanelle. This site is probably determined by the vascularity accompanying growth, as this is the last portion of the cranium to become bony. Such nodes are, therefore, analogous to the rings or collars that form in the long bones of syphilitic children near the epiphyses; the immobility of the cranial bones, however, causes the exudate to harden rather than to take on inflammatory action. The bulging of the forehead in some hereditary syphilitics is due to the catarrh of the frontal sinuses which often accompanies the Schneiderian catarrh, that produces first the so-called "snuffles" and later caries of the nasal bones, with the characteristic flattening of the nose.

In adults syphilis of the cranium usually causes necrosis, spreading from the external to the internal table. Necrosis from whatever cause is more apt to affect the external table, which is more exposed to injury and less richly supplied with blood.

The calvaria is far more frequently attacked by disease than the base, doubtless from its greater liability to traumatism.

The bones of the cranium are supplied with blood by arteries entering from the pericranium on one side and from the dura mater on the other. The dural supply is the larger; hence the foramina on the inside of the cranium are larger and more numerous than those on the exterior, and hence also traumatic detachment of the pericranium over considerable areas may not result in necrosis. When detached from disease, the latter (as in syphilis), even when originating externally, is apt to spread along the vessels, and thus cause necrosis by finally affecting the dural supply.

The meningeal blood-vessels running on the exterior surface of the dura—the remnant of the primitive membranous cranium (Humphry)—and sending branches to the cranium are not very strong, and consequently do not offer much resistance to the separation of the dura from the skull; neither do their branches furnish a very large quantity of blood, surgically considered. It follows that a traumatic separation of the dura is not in itself a lesion followed by serious consequences, unless the separation takes place at or about the situation of the main trunks. Hence, when an extradural clot is suspected to be the cause of grave symptoms, it is usually sought for first over the anterior inferior angle of the parietal bone,—*i.e.*, about three centimetres (approximately one inch and a quarter) behind the external angular process on a level with the upper border of the orbit. This will make accessible the region of the main trunk and the anterior branch of the middle meningeal. This latter branch at this point runs through a bony canal on the inner surface of the cranium, and is therefore frequently torn when fracture occurs in this region. An opening on the same level, but just below the parietal eminence, will permit the posterior branch to be reached.

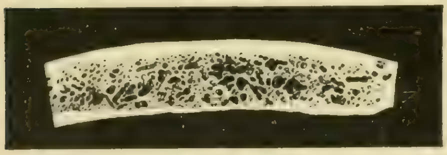
The venous channels (emissary veins) connecting the sinuses within and the superficial veins without the cranium sometimes convey infective disease, such as erysipelas or cellulitis of the scalp, and thus bring about a septic meningitis or sinus thrombosis.

The time-honored custom of blistering or leeching behind the ear in intracranial inflammations rests on the fact that the largest emissary vein is the mastoid, traversing the mastoid foramen and connecting the lateral sinus with an occipital vein or with the posterior auricular. (For further discussion of these channels of communication, see the section on the Venous System.)

While the spinal dura mater has no intimate connection with the inner surfaces of the vertebræ (being separated from the arches by adipose tissue and from the bodies by the posterior ligament), the dura mater of the cranium becomes closely attached to the bones, especially at the base, where it adheres tightly to the many ridges and prominences and to the edges of the foramina which transmit the nerves and vessels. To the sides and summit of the skull the dura is less closely attached; hence in fractures at the base the dura is generally torn, and the risk both of serious hemorrhage and of infection is thereby increased, while in fracture of the calvaria it much oftener escapes.

Fractures of the Cranium.—That fractures in this region are not vastly more frequent is due to various factors; among them are the rounded shape of the calvaria, causing blows to glance off; the division of the separate bones into inner and outer tables, with the comparatively spongy diploë intervening; and the curved thickenings which, like buttresses, strengthen the skull externally, and extend on each side through the supra-orbital ridge and the upper border of the temporal fossa to the mastoid process and thence to the occipital tuberosity. From this latter point on the inner surface other ridges, like the groining of a roof, run forward in the median line to the frontal bone, downward to the foramen magnum, and laterally, on either side of the groove for the lateral sinus, extend to the mastoid. In very young persons the dome of the skull is made up of three distinct arches composed of the occipital, the frontal, and the parietal bones. In childhood the centre (the most prominent portion) of each of these bones is, on account of early ossification, thicker than the rest, while the edges are connected by membrane and are comparatively movable. These mechanical conditions, together with the elasticity of the individual bones in young persons, make fractures of the skull in them comparatively rare.

Fig. 263.

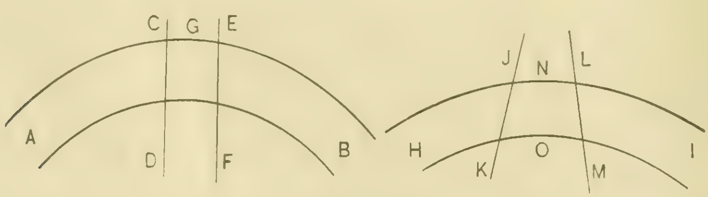


Section of frontal bone, natural size, showing relation of external and internal tables of compact bone to intervening diploë.

In the adult the membranous layer between the sutures becomes thinner or disappears and the bones denser and less elastic; they are, therefore, more easily fractured.

The two tables may be broken separately, although this is rare. In almost all cases in which fracture is complete the inner table suffers more than the outer. This is because (*a*) it is more brittle; (*b*) the fibres on the side of greatest strain suffer most (as in "green-stick" fracture); (*c*) the material carried inward from without is greater at the level of the inner table than at the point of application of the external force.

Agnew explains this diagrammatically as follows:

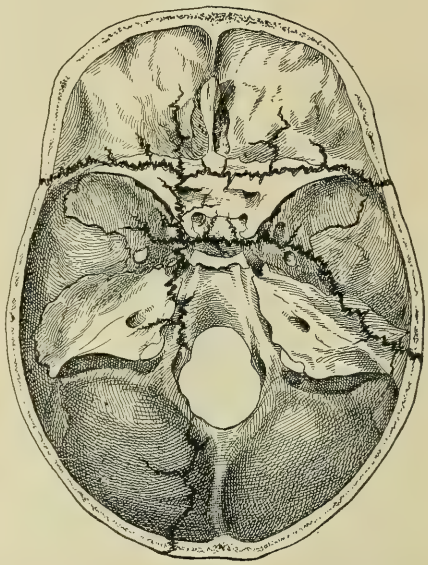


AB represents a section of the arch of the skull. CD and EF represent the lines of a vertical force applied about G. The effect is to flatten the curve so that it is as HI, while at the same time the vertical lines diverge (JK and LM) and the particles of bone in the external table tend to be forced together at N and separated or burst apart at O.

Force applied to the vertex would tend to drive apart the lower borders of the parietal bones, but the bases of the great arch formed by these bones are overlapped by the squamous portions of the temporal, and thus this outward thrust is prevented. If the force be applied to the frontal bone, as it overlaps the parietals at the middle of the coronal suture, it is transmitted to them and is resisted by the same mechanism. The occipital bone and the bones at the sides of the skull (beneath the level of the ridges that have been described) break more easily, as they are thinner, the diploë is less developed, and the two tables are more closely united (Humphry); but from their situation they are less exposed to injury, and are protected by a thicker covering of soft parts.

Fractures of the base are usually due to indirect violence. They may result from foreign bodies thrust through the nose, orbit, or pharynx; or from a blow upon the nose acting through the bony septum to produce fracture of the cribriform plate of the ethmoid; or through a blow or fall upon the point of the chin, driving the condyles of the inferior maxilla into the cranium. As a rule, however, the force traverses the vault or, more rarely, the spinal column (as in falls upon the feet or buttocks).

Fig. 264.



Base of skull from above, showing lines of fractures.

Fractures of the base are very frequent for several reasons. The large expanse of bone forming the vault is contracted at the base into three comparatively narrow portions, which descend in successively lower planes from before backward, but which all have relatively thin floors, on which the force received at a distant portion of the cranium is ultimately expended. This impact reaches the base by the shortest route, so that a blow of sufficient violence upon the frontal bone will fracture the orbital plates in the anterior cerebral fossa; upon the vertex, the petrous portion of the temporal and the floor of the middle fossa; and upon the occiput, the floor of the posterior or cerebellar fossa. Furthermore, the base is provided with a series of well-marked ridges which aid in the transmission of force and which fade away into the vault.

The anterior ridges are gathered into the lesser wing of the sphenoid and end at the sides of the anterior clinoid process.

The middle group, collected into the petrous portion of the temporal bone, passes to the centre of the base of the skull and terminates at the foramen lacerum medium.

The ridges of the posterior group, meeting at the torcular Herophili, continue to the foramen magnum, at the posterior limit of which they divide and pass forward to meet again in the basilar process, and end in the posterior clinoid process. The region of the sella turcica is therefore the centre of resistance to the transmission of forces from the vault to the base. This is well surrounded by fluid, and the vibrations which are concentrated here may thus become lost in the fluid without injuring the brain-substance.

The region of the middle fossa suffers, however, most frequently because: 1. It is connected (by the fronto-sphenoidal and petro-occipital sutures) with both the other fossæ, and hence often participates in their injuries. 2. It is intrinsically one of the weakest parts of the skull, on account of the presence of the foramina lacera, the carotid grooves, the hollows for the pituitary body, the depression for the sphenoidal sinus, the petro-sphenoidal suture, and the thin walls of the tympanum, of the external auditory canal, and of the temporal fossa. Moreover, just in front of this region the descending pterygoid processes and the lower jaw reinforce the

cranium proper, while behind it are the thickening of the basilar process and the posterior clinoid plate (Humphry) (Fig. 254).

The differential symptoms of fracture through the floors of these fossæ are determined by their anatomical relations. They are as follows :

1. *Anterior Cerebral Fossa.*—(*a*) Epistaxis when the Schneiderian membrane and the dura and arachnoid are torn. It should not be forgotten that the blood may come from the mucous membrane alone. (*b*) Loss of smell from injury to the olfactory bulbs resting on the cribriform plate. (*c*) Subconjunctival ecchymosis.

The blood is usually derived from the meningeal vessels over the orbital plates, but in bad cases may come from the ophthalmic artery, ophthalmic vein, or cavernous sinus. If the body of the sphenoid is fractured, the blood may find its way through the sphenoidal sinuses into the pharynx and stomach, and then be vomited, giving rise to a mistaken diagnosis of gastric injury.

2. *Middle Cerebral Fossa.*—(*a*) Hemorrhage from the ear. This may be merely from a torn tympanic membrane. (*b*) Escape of cerebro-spinal fluid from the ear. This indicates that the petrous portion of the temporal is broken, the dura mater and the arachnoid torn, and the membrana tympani ruptured. If the latter escapes injury, the fluid may trickle into the throat through the Eustachian tube. (*c*) In rare and very severe cases the lateral sinus has been opened or the internal carotid torn. (*d*) There may be deafness or facial paralysis, or both.

3. *Posterior or Cerebellar Fossa.*—(*a*) Hemorrhage into the pharynx if the basilar process is involved and the pharyngeal mucous membrane torn. (*b*) Ecchymosis at the nape of the neck and about the mastoid.

Of course the characteristic symptoms of any two or even of all three of these injuries may be commingled if the fracture is extensive enough.

Just as fractures would be more frequent were it not for the mechanism that has been described, so *concussion* or *laceration of the brain* would occur far oftener were it not for certain factors, among which are the different strata of varying density intervening between the brain and the outer surface of the scalp. The soft diploë and the dense inner "vitreous" table both tend to diminish shock to the brain, the former by arresting vibrations and the latter by lateralizing them. The eminences on the inner surface of the skull project into the spaces between the great divisions of the brain, where, in places, there is more subarachnoid fluid than elsewhere ; such elevations are intimately connected at their edges and terminal points with the strong expansions of the dura mater,—the falx and the tentorium,—which still further take up and distribute the final vibrations. "Thus there is every facility for causing jarring impulses to deviate from the direct line and take a circumferential route, in which they are gradually weakened and rendered harmless" (Humphry).

The conditions tending to minimize the effects of violence inflicted upon the skull are thus summarized by Jacobson : "(1) The density and mobility of the scalp. (2) The dome-like shape of the skull. This, like an egg-shell, is calculated to bear hard blows and also to allow them to glide off. (3) Before middle life the number of bones tends to break up the force of a blow. (4) The sutures interrupt the transmission of violence. (5) The internal membrane (remains of fœtal periosteum) acts in early life as a linear buffer. (6) The elasticity of the outer table. (7) The overlapping of some bones,—*e.g.*, the parietal by the squamous ; and the alternate bevelling of adjacent bones,—*e.g.*, at the coronal suture. (8) The presence of ribs or groins,—*e.g.*, (*a*) from the crista galli to the internal occipital protuberance ; (*b*) from the root of the nose to the zygoma ; (*c*) the temporal ridge from orbit to mastoid ; (*d*) from mastoid to mastoid ; (*e*) from the external occipital protuberance to the foramen magnum. (9) Buttresses,—*e.g.*, malar and zygomatic processes, and the greater wing of the sphenoid. (10) The mobility of the head upon the spine."

Landmarks.—The prominence of the occiput, of the parietal region, or of the frontal eminence indicates in a general way the development of the corresponding portions of the brain.

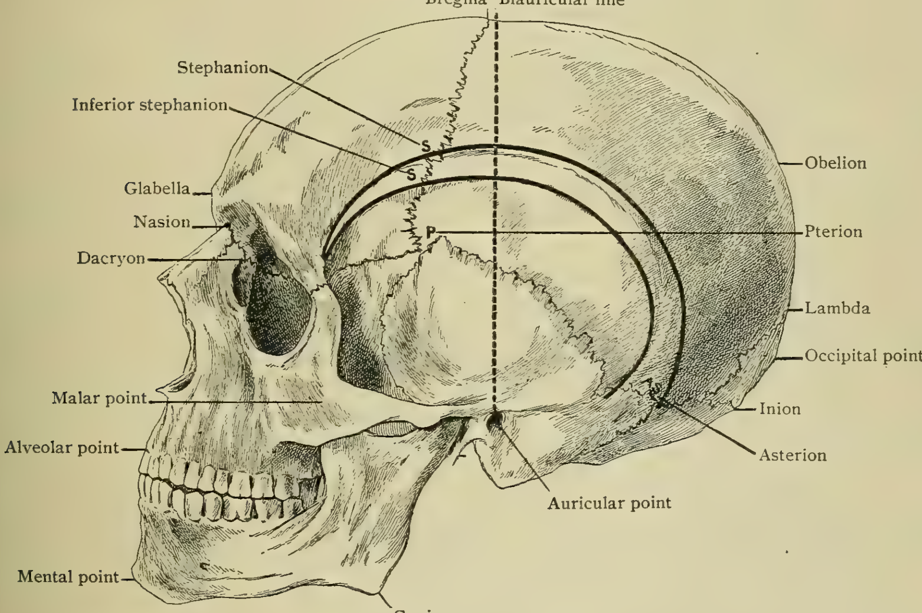
The terms used to designate particular points on the skull have already been described (page 228) ; additional attention may here be paid to those of especial importance as landmarks.

The *inion* or external occipital protuberance, which approximately corresponds to the point of convergence of five sinuses (the superior longitudinal, the two lateral, the straight, and the occipital), is easily felt in the mid-line behind. The superior curved lines which run outward from this point indicate the muscular origin of the occipito-frontalis, and hence are often the lower limit of effusions beneath the aponeurosis. These ridges indicate approximately the course of the lateral sinuses, which are on a line drawn from the inion to the superior border of the mastoid apophysis,—*i.e.*, to a point about 2.5 centimetres, or one inch, behind the external auditory meatus.

The *asterion* or junction of the squamous and lambdoid sutures is 12.5 millimetres, or half an inch, above and 18.5 millimetres, or three-quarters of an inch, behind the upper level of the posterior border of the mastoid. A line from the asterion to the inion is therefore also the line of the lateral sinus.

The *lambda*, the junction of the lambdoid and sagittal sutures, lies in the median line posteriorly about seventy millimetres, or two and three-quarters inches, above the inion. In early life the posterior fontanelle is found at that point.

FIG. 265.



Lateral aspect of the skull, showing the various points. (See also description on page 228.)

The *bregma*, the junction of the coronal and sagittal sutures (and in childhood of the frontal suture), marks the position of the anterior fontanelle, and is found a little anterior to the centre of the shortest line that can be drawn over the vertex between the two external auditory meatuses.

The *pterion* is the point of junction of the temporal, sphenoid, frontal, and parietal bones. It is from thirty to thirty-eight millimetres, or one and a quarter to one and a half inches, above the zygoma, and the same distance behind the external angular process of the frontal. It represents the position of the trunk and of the large anterior branch of the middle meningeal artery.

The *zygoma* can easily be traced from its anterior to its posterior extremity.

The *temporal ridges* can often be felt as two curved lines, the upper one marking the attachment of the temporal fascia and the lower one that of the muscle. They indicate the upper boundary of the temporal fossa, and often limit the spread of effusions or the growth of tumors.

The course of the *longitudinal sinus* is indicated by a line drawn from the nasion (the junction of the nasal and frontal bones) to the inion.

The *lateral sinus* is irregular in its course (page 234). According to Macewen, it may be fairly indicated by the two following lines: "The first from the asterion to the superior margin of the external osseous meatus, of which line the posterior two-thirds correspond to the upper part of the sigmoid groove, which is also the more superficial. The second line from the parieto-squamo-mastoid junction to the tip of the mastoid process corresponds in its upper two-thirds to the vertical part of the sigmoid groove. The knee of the sigmoid—its most anterior convexity—is variable in its position, but is generally on a level with the upper part of the external osseous meatus. The sigmoid groove is situated at a variable distance from the external auditory meatus, the tympanum, and the exterior of the skull. The distance between the external osseous meatus and the sigmoid groove varies from one or two to thirteen millimetres."

The frequency with which infective thrombosis of the lateral sinuses occurs as a complication of middle ear disease renders the topographical anatomy of these sinuses and the associated region of the skull of great practical importance.

The *suprameatal triangle* is formed by the posterior root of the zygoma running somewhat horizontally above, the portion of the descending plate of the squamous which forms the arch of the osseous part of the external auditory meatus below, and a base line uniting the two, dropped from the former on a level with the posterior border of the external auditory meatus. At this point there is usually a depression in the bone, though occasionally there is a slight prominence as if the antrum had bulged at that point. The apex of this triangular depressed area points forward (Macewen). The mastoid antrum may be reached through this triangle.

(The relations of this antrum, the facial canal, and the lateral sinus to one another, to the temporo-sphenoidal lobe, and to the surface of the skull will be considered in connection with the general subject of Cranio-Cerebral Topography, page 1214.)

The size and extent of the *frontal sinuses* vary, as described on page 234. The communication of these sinuses with the nose accounts for the frontal headache in ozæna, and the fact that a patient with a compound fracture opening up the sinuses can blow out a flame held close by. The frontal sinuses may be occupied by bony or other tumors; emphysema may result from fracture of the sinus wall; insects may gain access to these cavities and give rise to infection or to epistaxis; infective inflammations of the nose and naso-pharynx may involve the sinuses.

The *sphenoidal sinuses* are less important surgically, but these points should be remembered: (1) fracture through them may lead to bleeding from the nose, which is thus brought into communication with the middle fossa; (2) the communication of their mucous membrane with that of the nose may explain the inveteracy of certain cases of ozæna; (3) here and in the frontal sinuses very dense exostoses are sometimes formed (Jacobson).

The Face.—The nasal bones are so joined together as to form a strong arch resting upon the nasal processes of the superior maxillary bones. They are seldom dislocated, because this line of union is one in which there is an alternation in the bevelling of the sutures (similar to that between the frontal and parietal bones). Thus the lower portion of the nasal bones overlaps the maxillary, while nearer the root of the nose the latter is external. The line between the bones and the nasal cartilages can easily be felt. The skin is very tightly attached to the cartilages.

The upper or frontal portion of these bones is very strong, and will resist a great degree of force without fracture. The lower portion is most frequently broken, usually within a half-inch of the lower margin.

The resulting deformity is usually lateral, but if the perpendicular plate of the ethmoid is broken the nose will be depressed. The thinness and close application of the mucous membrane to the bones render these fractures almost invariably compound. Emphysema of the cellular tissue of the face and forehead may follow such an injury. The vascularity of the bones leads to very rapid union, and it is therefore

important to secure early reposition of the fragments. The relation of the perpendicular plate of the ethmoid through the crista galli to the olfactory bulbs and the base of the brain should be remembered in severe injuries to the bones of the nose. By reason of this relation suspension or destruction of the sense of smell has resulted; and even septic meningitis and death have followed accidents in which the prominent early symptom was fracture of the nasal bones.

The *malar bones*, binding together the maxillæ and the cranium, are very strong, and seldom broken unless by severe force directly applied.

Fracture of the body is apt to run into the orbit, producing a subconjunctival ecchymosis near the outer canthus, and there may also be a loss of sensation in some of the teeth, the gums, the ala of the nose, and a part of the cheek, on account of injury to, or pressure upon, the infra-orbital branch of the fifth nerve.

The *zygomatic process* is most subject to fracture; that part of the arch which is on the temporal side of the suture is much weaker and most apt to give way. The deformity may usually easily be recognized by touch. The fragments are always driven inward, and sometimes become entangled in the fibres of the temporal muscles. The attachment of the strong temporal fascia to the upper edge of the zygoma, and of the masseter muscles to its lower edge, prevents displacement upward or downward.

The *superior maxilla*, on account of its very various and complicated relations (being associated with nine other bones), has considerable surgical importance. Its position in the same vertical plane as the forehead (instead of in advance of it, as in the lower animals) indicates the limitation of its function to mastication, the need for its use in prehension having disappeared. Many of its diseases (infections, tumors, etc.) originate in the teeth or teeth-sockets, and may be avoided by early attention to these structures. Others arise by reason of the contiguity of the maxillary antrum to the inferior turbinated bone, the mucous membrane of which is often the subject of chronic catarrh.

Injuries of the superior maxilla causing fracture must, as a rule, be direct and of considerable violence. The line of fracture may involve the antrum, the nose through the nasal process, the orbit through the orbital process, or the mouth through the alveolar or palatine process. It may also run into the zygomatic or the spheno-maxillary fossa. The force may be transmitted from the malar bone, or from the lower jaw through the teeth.

The maxilla is very vascular, and hence recovery from even serious or crushing injuries is apt to be rapid and thorough. Like the nasal bones, it has attached to it no muscles that can cause or perpetuate deformity, and therefore, unless it is comminuted, its fragments will retain their position when once replaced.

It is frequently affected by "phosphorus necrosis," the osteitis causing the necrosis being probably due to the direct toxic action of the phosphorus fumes gaining access through carious teeth. This theory is not undisputed.

Tumors involving the alveolar border show first in the mouth. Tumors of the body usually occupy the antrum (maxillary sinus). They are apt to grow in every direction except towards the malar bone, where they meet with the greatest resistance. They accordingly produce prominence of the eye from pushing upward the floor of the orbit, bulging of the cheek from pushing outward the thin anterior wall, and depression of the roof of the mouth from pressure upon the palatal plate. After the anterior the most yielding wall of the antrum is the orbital.

Abscess of the antrum gives rise to the same symptoms when it attains a large size.

The relations of the molar teeth to the floor of the antrum and of the infra-orbital nerve to its roof account for the toothache and facial neuralgia that so often accompany antral disease. It is said to be a fact that cystic distention does not involve the lachrymal duct, while solid tumors may cause overflowing of the tears (Warren-Heath).

The chief *deformity* associated with the superior maxilla is cleft palate, which results from a failure of the palatal plates to unite in the median line. The cleft in the hard palate is always median, but when it reaches the alveolus it follows the line of the suture between the premaxillary bone (os incisivum) and the superior

maxilla, ending, therefore, opposite the space between the lateral incisor and the canine. In single harelip, which is often associated with cleft palate, and due to faulty union of the fronto-nasal and maxillary processes (page 60), the gap is found at the same point, never in the middle line. Sometimes the premaxillary bone, which carries the two upper central incisors, is left attached to the nose. This condition is usually associated with double harelip. Cleft palate may involve only the soft palate and not the hard, but the reverse is almost never true.

Occasionally the identity of the premaxilla is established pathologically. Instances of exfoliation of this bone carrying the two incisor teeth have been recorded, not only in children but even in adults.

Excision of the superior maxilla involves (the bone having been exposed by a suitable incision through the soft parts) the disjunction of (*a*) its connection with the malar bone; (*b*) its nasal process from the nasal, lachrymal, and frontal bones; (*c*) its orbital plate from the ethmoid, malar, lachrymal, and palate bones; (*d*) its posterior connection with the pterygoid processes and palate bone; and (*e*) its articulation with its fellow through the palatal plates and its connection with the soft palate.

These indications are met, as a rule, by sawing through the malar bone just beyond its articulation with the maxilla (so that advantage may be taken of the proximity of the spheno-maxillary fissure), dividing the nasal process a little below the junction with the nasal bones, sawing through the hard palate (from the nose downward) at or beyond the median line, dividing the orbital plate with a fine chisel (or leaving it to be brought away at the last step), and, finally, wrenching the bone away from its attachment to the pterygoid processes (and the orbit) by means of a pair of lion-forceps. The hinder wall, in contact with the palate bone, is very thin, and may give way and remain behind at this stage. This is most likely to happen when it is most undesirable,—*i.e.*, when the operation is performed for malignant disease.

The *inferior maxilla*, the only bone of the skull which is movable upon the others, is especially dense, so that it may be strong enough to withstand the very considerable force which its muscles exert upon it in mastication. It is, therefore, not easily divided in operations. The alveolar processes are thicker and stronger than those of the upper jaw, and more force is, therefore, usually required to extract a tooth; hence damage to the bone through rough or unskilful effort at extraction is more frequent in the lower than in the upper jaw. The last molar, or wisdom tooth, is often a cause of trouble, owing to the limited space it occupies near the angle between the ramus and the body of the jaw. The smaller that angle the greater the difficulty in cutting this tooth, which may be compelled to carry before it a portion of the gum closely applied to the base of the coronoid process, causing inflammation or ulceration, or, through irritation of the sensory branches of the fifth nerve, may even produce trismus, since the motor supply of the muscles of mastication is derived from the same nerve-trunk. It is thus much oftener the source of trouble in the white races than in negroes, in whom the angle between the ascending and horizontal portions of the bone is more obtuse.

Congenital deformities of the lower jaw are very rare. When they do occur, as in a case reported by Humphry, they show that the jaw consists essentially of two portions, the alveolus and the remainder of the jaw. In that case the jaw in adult life preserved the proportions of infancy so far as the body was concerned, but the teeth and alveolus had attained normal dimensions. The division, as Allen has emphasized, is an important one to remember for the following reasons: the alveolus is developed with the teeth; it is an outgrowth from the jaw for a specific temporary purpose. John Hunter declared that the "alveolar processes of both jaws should rather be considered as belonging to the teeth than as parts of the jaws." Hence all diseases of the alveolus are to be considered as dental in their significance. Epulis, or fibroma of the gums, is essentially an alveolar disease. A tooth in any portion of the jaw other than the alveolus is a foreign body. If it is lodged beneath the alveolus, it may give rise to chronic abscess, or may, through long-continued irritation, cause one of the various forms of odontomata. Cystic disease about the angle of the jaw is often excited by a misplaced third molar.

The inferior maxilla has no epiphysis, and, as might therefore be expected, the ends of the bone at and near the articular surfaces are usually exempt from disease, in marked contrast to the long bones, in which those regions especially suffer.

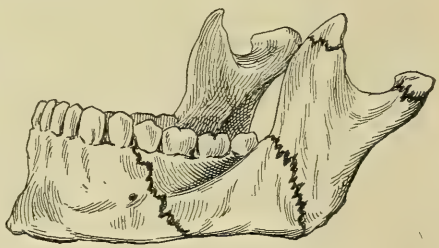
The inferior maxilla is not a very vascular bone; the mucous membrane of the gum is in close contact with it; it occupies a peculiarly exposed position, and is subject to frequent minor traumatisms; it is readily infected through carious teeth or tooth-sockets. Such a tooth or an open socket communicates directly with the cancellous tissue of the bone, thus probably permitting in the lower, as in the upper jaw the direct contact of the toxic agent in phosphorus necrosis. Similar conditions are found in no other bones of the skeleton.

As a result of the conditions just enumerated, osteitis and necrosis are common, are associated with much pain, and are often very slow in their progress.

The excessive pain, dysphagia, dribbling of saliva, and occasional aphasia and marked nervous symptoms are thought to be due to reflex irritation associated with compression of the inferior dental nerve in the dental canal by the products of inflammation. Such irritation of a cranial nerve confined within a bony canal is rare, and associates the above symptoms with those occasioned by pressure from similar causes on the other branches of the fifth pair and on the seventh.

Fracture of the lower jaw may occur at any point. The whole bone is to a great extent protected from fracture by its horse-shoe shape, which gives it some of the properties of a spring, by its density of structure, by its great mobility, and by the buffer-like interarticular cartilages that protect its attached extremities (Treves).

FIG. 266.



Mandible, showing lines of fractures.

The neck of the condyloid process and the coronoid process are so deeply situated and so sheltered in the temporal fossa by the zygomatic arches that they are seldom broken.

The ramus is protected (though to a less extent) by the masseter externally and the internal pterygoid internally, and is not often fractured. The angle and the symphysis are thickened, and thus resist fracture.

About three centimetres (approximately one and a quarter inches) laterally to the symphysis the bone is weakened by the presence of the mental foramen and the large socket for the canine tooth. It is most often broken there or thereabouts either by direct or by indirect violence. Most fractures of the body of the bone are compound on account of the firm adhesion of the gum, which is usually torn; hence necrosis and non-union following infection from the mouth-fluids are not uncommon results. (For the displacement accompanying this fracture see section on Muscles, page 493.) The deformity, in so far as it is produced by anatomical forces, is apt to consist of depression of the anterior and larger fragment by the digastric, the genio-hyo-glossus, and the genio-hyoid, and elevation of the posterior and smaller fragment by the temporal, the masseter, and the internal pterygoid.

The dental nerve, while escaping injury at the time of the accident, may later be compressed by callus, and, if irritated, may, by reason of its anatomical associations with the regions in front of the pinna or in the external auditory meatus, give rise to "faceache" or to "earache." If paralyzed, and the patient puts a cup to his lips, he feels with his lower lip only half of it; in paralysis of the fifth nerve itself it seems to him exactly as though it were broken (Owen).

The capsule of the *temporo-maxillary joint* is thinnest anteriorly and strongest externally; hence suppuration is most likely to extend in a forward direction. The strong external lateral ligament arising from the lower edge of the zygoma and running backward and downward seems to prevent the condyle being pressed backward against the bony meatus and the middle ear (Fig. 247). As Treves observes, if it were not for this provision, blows upon the chin would be far more dangerous than they are.

In spite of its great mobility and its frequent use, the joint is rarely the subject

of acute disease, the intra-articular cartilage being so arranged (page 214) that it acts as an elastic buffer presenting one surface upon which the hinge-like, and another upon which the sliding, movement of the jaw may take place. Suppurative disease of the middle ear may extend to the joint (Barker).

Rheumatoid arthritis is perhaps the most common disease of the joint, and may be localized there in subjects otherwise predisposed by the frequent exposure of the joint to cold and wet.

The so-called "subluxation," sometimes, perhaps, depending upon relaxation of the ligaments, is more probably in the majority of cases due to rheumatic or gouty changes in the joint.

Dislocation of the jaw (discussed in connection with the action of the associated muscles, page 493) occurs only when the mouth is widely open, as in yawning, so that the condyle passes beyond its proper limits, over the summit of the ridge, and is lodged in front. "When the mouth is widely opened the condyles, together with the interarticular fibro-cartilage, glide forward. The fibro-cartilage extends as far as the anterior edge of the eminentia articularis, which is coated with cartilage to receive it. The condyle never reaches quite so far as the summit of that eminence. All parts of the capsule save the anterior are rendered tense. The coronoid process is much depressed. Now, if the external pterygoid muscle (the muscle mainly answerable for the luxation) contract vigorously, the condyle is soon drawn over the eminence into the zygomatic fossa, the interarticular cartilage remaining behind. On reaching its new position it is immediately drawn up by the temporal, internal pterygoid, and masseter muscles, and is thereby more or less fixed. A specimen in the Musée Dupuytren shows that the fixity of the luxated jaw may sometimes depend upon the catching of the apex of the coronoid process against the malar bone" (Treves).

Excision of the inferior maxilla, since it is concerned chiefly with the soft parts, will be considered in connection with the Muscles (page 493).

Landmarks.—The supra-orbital ridges mark the boundary between the face and the cranium. The supra-orbital notch can be felt at the junction of the inner and middle thirds of the supra-orbital margin. A line from that point to the interval between the two bicuspid teeth in both jaws crosses the infra-orbital and the mental foramina (Holden).

The attachment of the nasal cartilages to the superior maxillæ and to the nasal bones can easily be felt. The connective tissue between the skin and the cartilages is very scanty. This is a source of difficulty in some of the plastic operations on the nose, and is also a cause of the severe pain felt in cellulitis and in furuncles of that region. The great vascularity of the part and the fact that "the edge of the nostril is a free border and the circulation therefore is terminal" (Treves) favor congestion and engorgement, while the close connection of the skin and cartilage resists the swelling; hence the nerve-pressure and the excessive pain.

The malar prominence, the concavity of the superior maxilla representing the anterior wall of the antrum, its malar process, corresponding to the apex of that cavity, the incisor fossa, and the canine fossa can easily be recognized either through the cheek or, more readily, through the gums with a finger in the mouth.

The zygoma can be both seen and felt, the lower border more distinctly than the upper on account of the attachment to the latter of the dense temporal fascia. Wasting diseases cause an apparent increase in the prominence of the zygoma.

The condyle of the inferior maxilla can be outlined and its motions observed (Fig. 246) just in advance of the ear.

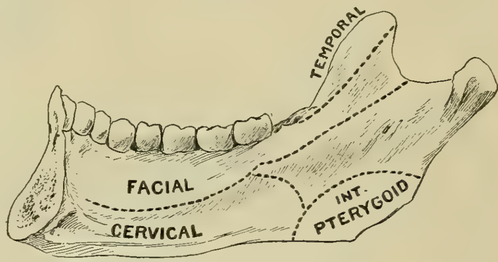
A line drawn from the angle to the condyle indicates the posterior border of the ramus. In making incisions in this region for inflammatory or suppurative conditions this line is to be remembered. Posterior to it important blood-vessels may be injured; anterior to it deep punctures may be made with safety, the only structure of consequence endangered being branches of the facial nerve.

From the angle of the jaw forward the outline of the inferior maxilla can be seen and felt both externally and within the mouth. The alignment of the teeth is usually disturbed in fracture, and is often the most easily recognized symptom. With a finger between the cheek and the teeth, the anterior border of the coronoid

process may readily be defined. In dislocation this is unnaturally prominent. Between its base and the last molar tooth there is often a space through which liquid food or other fluids can be conveyed by a tube to the pharynx in cases in which fracture-dressing, or trismus, or ankylosis renders the lower jaw immovable. Along the lower border externally, just in advance of the anterior edge of the masseter, the groove for the facial artery may be felt, and in the middle line the ridge which indicates the thickening at the symphysis.

On the inner surface of the jaw may be recognized the genial tubercles, sometimes in two distinct pairs, indicating the attachments of the genio-hyoglossi and genio-hyoidei. The sublingual fossæ may be located, and just external to them, and at their lower border, the faint beginning of the mylo-hyoid ridge, which runs upward and backward, becoming more evident opposite the last two molars.

Fig. 267.



Inner surface of lower jaw, showing various areas.

Above this line the bone is covered by the mucous membrane of the mouth ; hence diseases of this portion find their expression in the oral cavity, while those of the lower portion of the bone are more apt to involve the soft parts and glands of the neck (Fig. 267). The fossæ for the submaxillary glands cannot be felt through the mouth, but, as they lie below the ridge, while the sublingual fossæ lie above it, the well-known clinical relations of the former glands to the neck and of the latter to the mouth are explained.

The familiar change in the shape of the lower jaw in edentulous old persons is due to absorption of the alveolar process.

(Most of the landmarks of the face are of more importance in relation to the soft parts, the nerves, and the contents of the cavities of the orbit, nose, and mouth than in connection with the bones themselves. They will, therefore, be further considered in those connections.)

THE UPPER EXTREMITY.

The Shoulder-Girdle.—This consists of the clavicle and scapula. The latter is far the most important morphologically, representing, as it does, both the scapula and the coracoid of the lower classes of vertebrates; while the clavicle is inconstant in mammals, and seems to be no part of the primitive shoulder-girdle. The scapula bears the socket for the humerus. It has no bony attachment to the trunk save through the clavicle, which, interposed between it and the sternum, is connected with both by joints.

THE SCAPULA.

Physiologically, the essential part of the scapula is the socket for the shoulder; a part of this is made by the *coracoid element*, which in man is an insignificant process of the shoulder-blade. The secondary functions of the bone are to give origin to some muscles and to afford leverage to others for their action on the arm. In most mammals the scapula may be considered a rod running upward from the joint, from which three plates expand, one towards the head, one towards the tail, and one outward. In man the second of these plates points downward and is excessively developed. It is more convenient in man to speak of one main plate, the *body* of the scapula, with the *spine* springing from the dorsal surface.

The **body** is triangular, with two surfaces,—a ventral one towards the ribs and a free dorsal one,—three borders, and three angles.

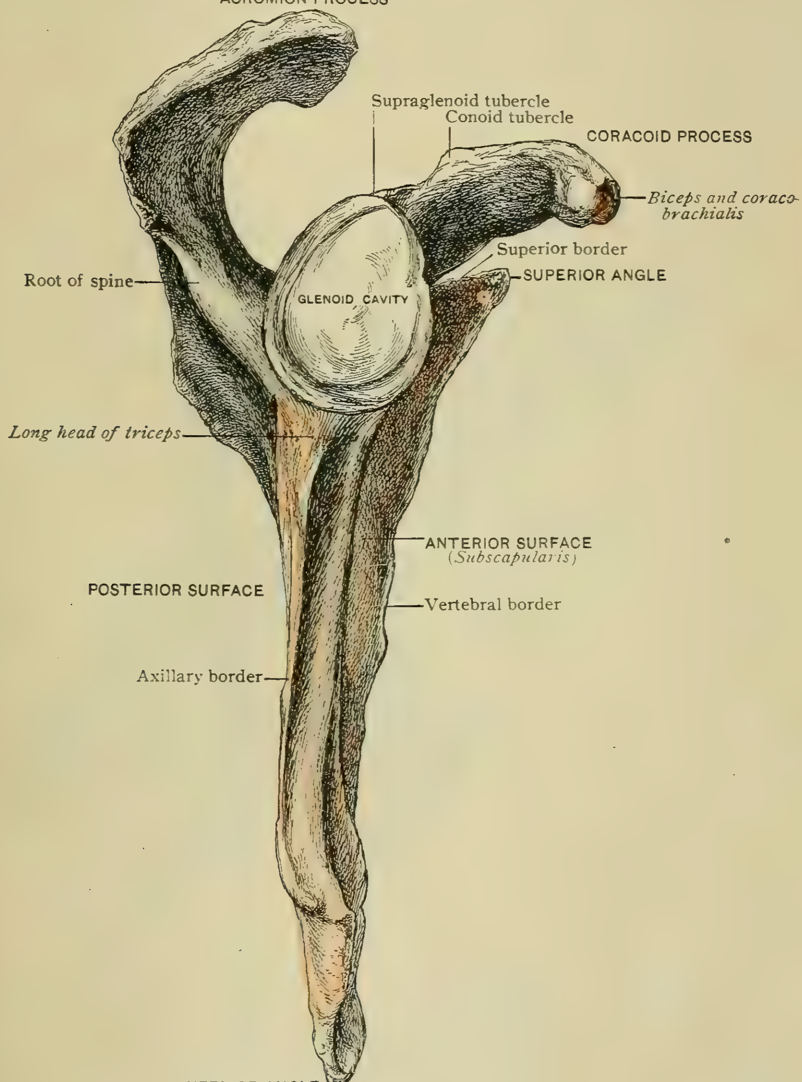
The **posterior** or **vertebral border**,[1] sometimes called the *base*, is the longest. It is nearly vertical from the lower angle to a triangular space on the dorsum, opposite the origin of the spine, above this it, as a rule, slants forward, but at a very varying angle. The **upper border**[2] slants downward and forward to the *suprascapular notch*[3] at the base of the coracoid process. This notch, transmitting the suprascapular nerve, is sometimes imperceptible, but usually is well marked and sometimes very deep. It is bridged by a ligament, which may be replaced by bone, transforming the notch into a foramen. The **anterior** or **axillary border**[4] is the only thick one. Just below the glenoid cavity it begins as a triangular roughness for the long head of the triceps. This is continued as a line which ends on the dorsal surface near the lower angle, a little above an unnamed process curving forward and inward from which a part of the teres major arises. This is the analogue of a process much developed in some small monkeys. It is sometimes very large, the increase of size being in no relation to that of the bone nor of the muscle. Above this on the anterior border there is a deep groove for a part of the subscapularis muscle just internal to the anterior edge proper. Below the process the border runs downward and backward to the **inferior angle.**[5] This angle is sometimes very sharp, sometimes quite the reverse. The same, in a less degree, may be said of the **upper angle**,[6] usually sharp, sometimes squarely truncated. The **anterior angle**[7] is the *glenoid cavity*. This, with the base of the coracoid process, is called the *head* of the scapula, the *neck* being a constricted region behind it, reaching to the suprascapular notch. The **glenoid cavity**[8] is an oval, slightly hollowed, cartilage-covered surface expanding from a narrower base. The long axis is vertical and the broad end below. There is often an indentation at the upper part of the inner margin. The edge is a little raised where it bears the *glenoid ligament*, which deepens the cavity for the reception of the head of the humerus. The top of the edge forms the *supraglenoid tubercle*, whence starts the long head of the biceps.

The **coracoid process** springs from the top of the head just behind the glenoid cavity and a little to the inner side. The first part, or *root*, which is compressed from side to side, rises inclining somewhat inward. The second, the free projecting portion, irregularly cylindrical, runs forward, rather outward and downward, to end in a knob near the inner side of the shoulder-joint. The upper and inner surface is

[1] Margo vertebralis. [2] M. superior. [3] Incisura scapulae. [4] M. axillaris. [5] Angulus inferior. [6] A. medialis. [7] A. lateralis. [8] Cavitas glenoidalis.

rough and convex, the under and outer smooth and concave. A rounded prominence, the *conoid tubercle*, for the conoid ligament, is situated on the top of the first part and rather to the inner side, just above the angle formed by the two parts. A ridge from behind this, running outward and forward, separates the two parts distinctly. The *trapezoid ridge* for the trapezoid ligament runs forward from the conoid tubercle along the inner side. The outer side of the upper aspect has a ridge for

FIG. 268.



Right scapula from before.

the coraco-acromial ligament. The short head of the biceps and the coraco-brachialis arise from a roughness at the tip of the process, and the pectoralis minor inserts into one at its inner side.

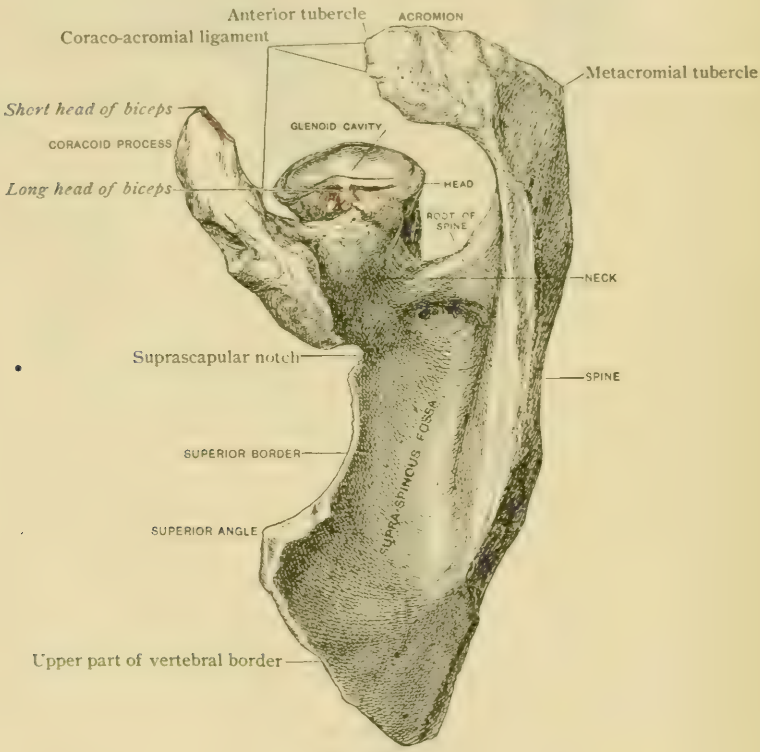
The **anterior surface**, or **venter**,[1] is concave, forming the *subscapular fossa*, the deepest hollow being along the origin of the spine. At the very top the bone often takes a turn outward. The serratus magnus is attached to rough surfaces inside the upper and lower angles and to a narrow line connecting them just beside

[1] Facies costalis.

the vertebral border. These surfaces are separated from the rest of the fossa by well-marked lines, which, with some four ridges running forward and upward from the spinal border, give origin to tendinous septa from which the subscapularis springs. This muscle arises also from the deep groove inside the axillary border.

The **posterior surface**,[1] or dorsum, is divided by the spine into a *supraspinous* and an *infraspinous fossa*. The former gives origin to the supraspinatus. Near the back it is often strengthened by a vertical swelling. The *infraspinous fossa* is chiefly occupied by the infraspinatus, but two other areas are marked off by two lines: one, running forward and upward, separates the dorsal side of the lower angle and of the unnamed process on the axillary border; from this space springs the teres major. The second line leaves the axillary border near the glenoid cavity and, diverging slightly, strikes the former line near the front, bounding a narrow region for the teres minor, which is crossed high up by a groove for the dorsal scapular artery.

FIG. 269.



Right scapula from above.

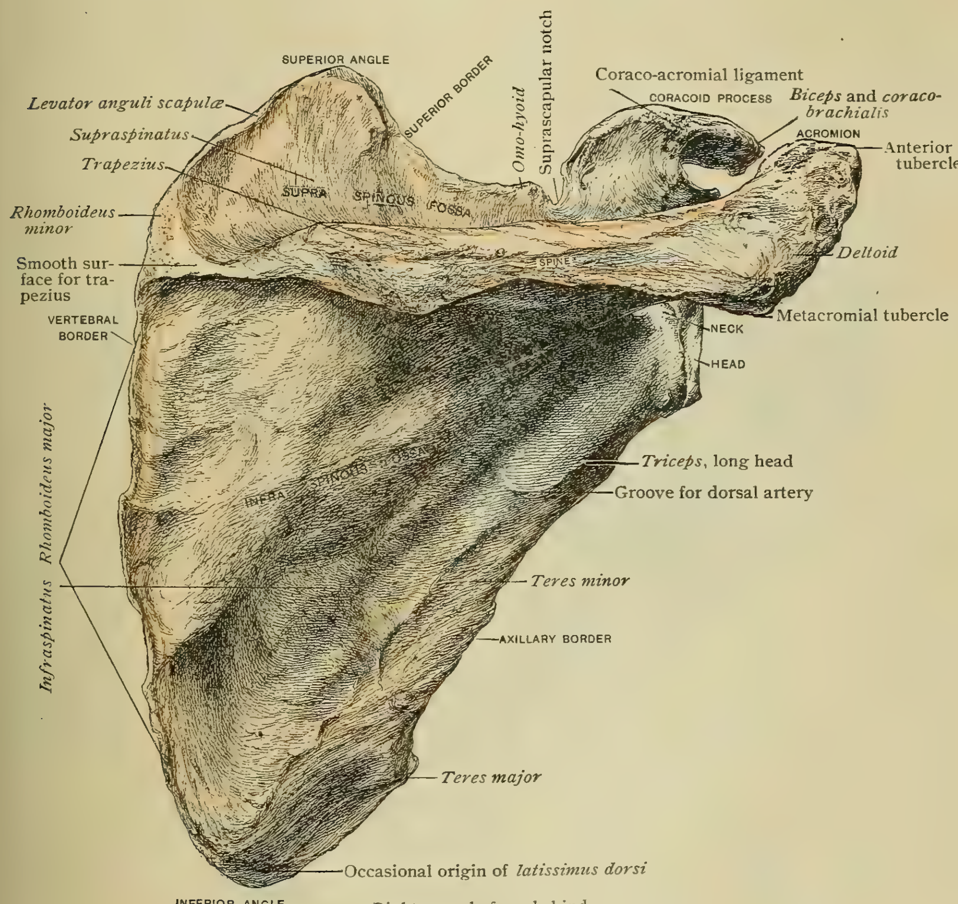
The **spine**[2] is a triangular plate arising from a small triangular surface at the posterior border, running outward and somewhat upward. Its attached border stops at the neck before reaching the glenoid cavity. The spine forms an acute angle with the floor of the supraspinous fossa, and an obtuse one with that of the infraspinous. Its front border is rounded and curves forward, and forms the posterior boundary of the *great scapular notch* connecting the supra- and infraspinous fossæ. The free border is narrow beyond the triangular area, but soon broadens, presenting an upper and a lower lip. The descending fibres of the trapezius are inserted into the whole length of the former, and of its continuation into the acromion. The lower lip often begins with a tubercle for the ascending and horizontal fibres, a little beyond which it narrows again. It gives origin to the deltoid muscle, which also is continued along the acromion.

The **acromion**[3] is a broad, flat expansion overhanging the shoulder-joint and articulating with the clavicle by an elongated facet slanting slightly upward. A

[1] Facies dorsalis. [2] Spina scapulae. [3] Acromion.

short *preclavicular border* in front of this, receiving the outer end of the coraco-acromial ligament, runs forward and outward to the *anterior tubercle*. From this the outer border runs backward to the *metacromial tubercle*, whence the posterior border runs into the hind edge of the spine. The *outer border* has three or four irregularities above for the tendinous septa of the deltoid, and is smooth at its lower edge for the same muscle. The lower lip of the spine runs directly into the hind border of the acromion, but often splits so as to enclose a narrow space continued into the back of the process, from which the deltoid springs. The acromion varies much in shape; according to this description it is quadrate; often, however, the pre-

FIG. 270.



Right scapula from behind.

clavicular edge is rudimentary, so that it is three-sided; or the metacromial tubercle is at the apex of a very obtuse angle, so that it is curved and narrow. There are also intermediate forms.[1] The inclination of the acromion to the horizon is on an average not far from 45°, with a variation of probably 15° either way. This may or may not depend on a corresponding variation of slant in the spine.

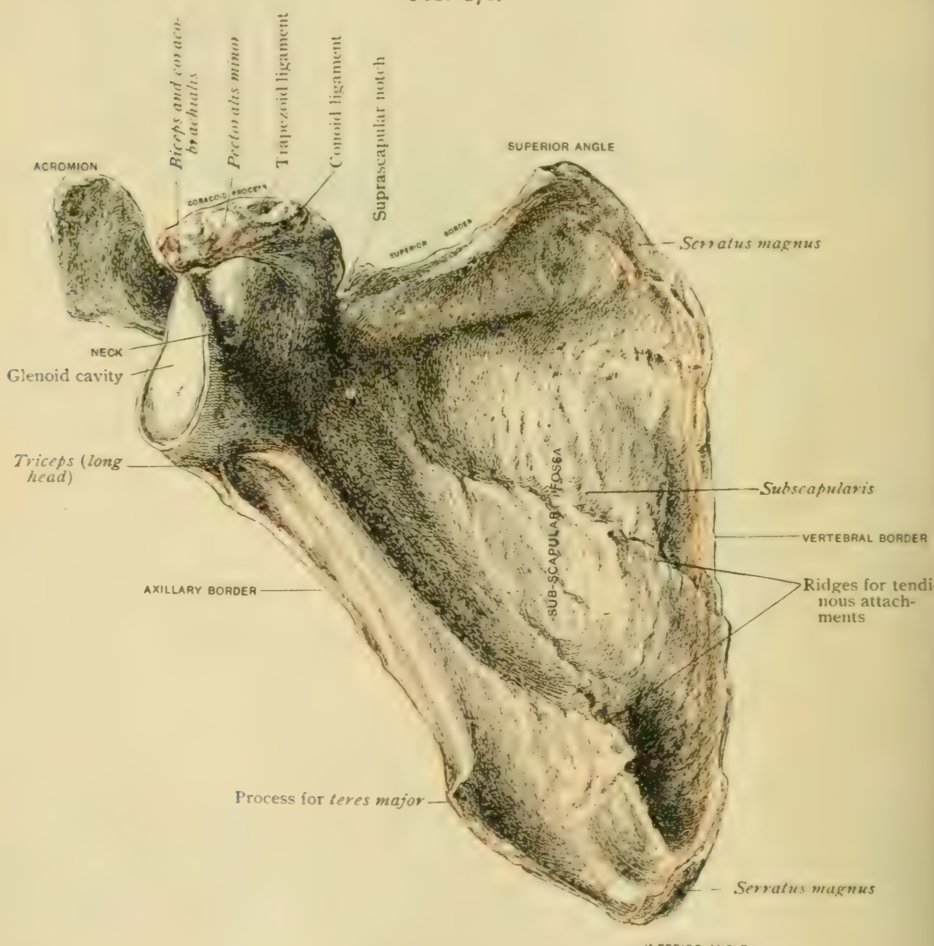
All the details determining the outline of the scapula vary greatly. The hind border may be convex, or the infraspinous portion concave. The bone lying with the dorsum up should rest on the coracoid and the upper and lower angles, with the vertebral edge rising from the table; but this may be almost straight, or even bend the other way so as to change the usual points of support. The *length* from the upper to the lower angle ranges from 13.2 centimetres

[1] Macalister: Journal of Anatomy and Physiology, vol. xxvii., 1893.

or less up to 20.1 centimetres. The *scapular index* is the ratio of the breadth, measured along the base of the spine, to the length $\left(\frac{100 \cdot \text{breadth}}{\text{length}}\right)$. It ranges from 55 to 82. The following means have been given for Caucasians: Broca, 65.9; Flower and Garson, 65.2; Dwight, 63.5. A high index means a broad scapula, which is one of a low type. The *infraspinous index* is the ratio of the breadth to the length of the infraspinous fossa, measured from the lower angle to the starting-point of the spine $\left(\frac{100 \cdot \text{breadth}}{\text{infraspinous length}}\right)$. This ranges from 72.3 to 100.2, with a mean of about 87. Although high indices imply a broad scapula, this method is of small value, as very diverse shapes may have similar indices. It is not possible to predicate anything of the figure during life from the shape of this bone. The most that can be said is that a long arm requires the leverage furnished by a long scapula.

Differences due to Sex.—The chief point is the size. From the study of eighty-four male and thirty-nine female bones it appears that of 123 bones, twenty-six measure less than fifteen centimetres in length, of which only three were male; also that seventy-six measure sixteen centimetres or more, of which only five were

FIG. 271.



Right scapula from before.

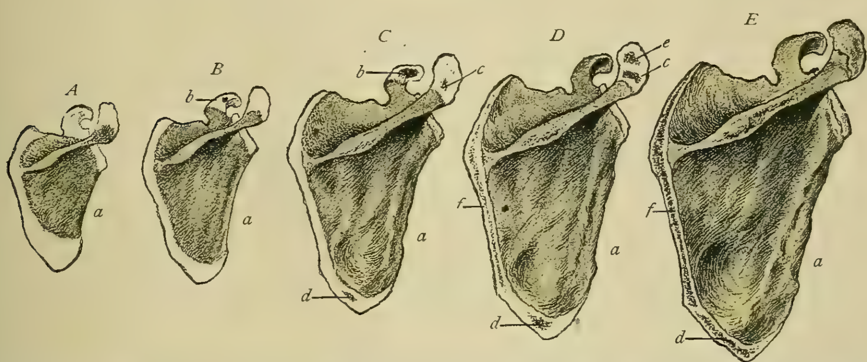
female. There was no single instance of a bone measuring less than fourteen centimetres being male, nor of one measuring seventeen centimetres being female. In doubtful cases the glenoid cavity is very valuable. In woman it is not only smaller, but relatively narrower. Very few male sockets are less than 3.6 centimetres in length, and very few female as long. The typical female scapula is very delicate;

the lower angle is sharp, the process on the front border small; the hind border straight up to the spine, then slanting forward in another straight line; the upper border descends sharply; the coracoid is slight, with the end compressed instead of knobbed; the acromion is curved and narrow. An expert should be reasonably sure of the sex four times in five. Doubtful bones are almost always male; so are those of peculiar shape, with the exception of concave vertebral borders. The scapular index has no sexual significance.[1]

Structure.—The strong parts are seen when the bone is held to the light. The head, neck, coracoid, acromion, and most of the spine are strong. So also are the front border, the lower angle, and, to a less extent, the hind border, which is strongest above the spine. Most of the body is very thin. A section through the socket, along the origin of the spine, shows the bony plates so disposed as to resist pressure in that line.

Development.—There is one chief centre for the scapula proper and one for the coracoid, besides an indefinite number of accessory ones. The first appears about the eighth week (Rambaud et Renault) at the neck, and forms nearly the

FIG. 272.



Ossification of scapula. *A*, at eighth fœtal month; *B*, towards end of first year; *C*, from fourteen to fifteen years; *D*, from seventeen to eighteen years; *E*, about twenty years. *a*, chief centre; *b*, for coracoid process; *c*, for acromion; *d*, for inferior angle; *e*, additional for acromion; *f*, for vertebral border.

whole bone, including the spine and the root of the acromion and the dorsal part of the root of the coracoid. The coracoid centre appears in the first year; it forms also the top of the glenoid cavity, and fuses with the first at fourteen or fifteen, beginning to unite at the ventral surface. At the earlier age the acromion is cartilage beyond a line drawn from the back of the clavicular facet to the front of the metacromion. At about fifteen many little nuclei appear in the acromion. The anterior tubercle is formed from a single nucleus; the others coalesce into two groups,—one in the centre, the other at the outer margin. At about eighteen the latter joins the body and the other two fuse. A year later the mass so formed also joins the body. Sometimes this remains connected by fibro-cartilage; very rarely several pieces persist. A scale-like epiphysis appears at the conoid tubercle of the coracoid about fifteen, and soon fuses. About seventeen or eighteen a nucleus appears in the strip of cartilage along the posterior border and one at the lower angle. Both are generally fused by twenty, but the lower is one of the last to fuse in the skeleton, and the line of union may remain for years.

PRACTICAL CONSIDERATIONS.

The scapula is rarely absent and rarely malformed. The outer part of the acromion may exist as a distinct bone, as may, but less frequently, the coracoid. Many cases of so-called fracture of the acromion and others of supposed traumatic separation of the acromial epiphysis are probably cases of persistent epiphysis. The centre for the inferior angle sometimes remains distinct, being united to the body

[1] Dwight: The Range and Significance of Variation in the Human Skeleton, Proc. Mass. Med. Soc., 1894.

by a synchondrosis. The possibility of its detachment by excessive action of the latissimus dorsi has been mentioned, but no case of traumatic separation has been recorded.

Fracture is rare, in spite of the thinness of much of the bone, because of its mobility, the adaptation of its curves to the underlying thoracic surface, the elasticity and compressibility of that surface, the thickness of the muscles that cover the scapula and of those that lie beneath it, the fragility of the clavicle (which by fracturing often saves the scapula), and the great range of movement and corresponding weakness of the shoulder-joint, which, in like manner, by undergoing luxation, prevents the force of the traumatism from reaching the scapula.

Fig. 273.

Lines of fracture of the scapula.

Fracture of the body and of the inferior angle from indirect violence has been reported in a few cases. The arms were fixed, and strong traction was being exercised in more than one case. It seems probable that the bone breaks between the opposing forces of the rhomboids and trapezius on the one hand, and the teres muscles, the subscapularis, and the infraspinatus on the other.

The most common fracture is that of the body, usually running transversely or obliquely through the subspinous fossa. The attachments of the subscapularis beneath and of the infraspinatus above usually prevent any marked displacement. There is pain on lifting the arm to a horizontal position, because, in order that the deltoid may be able to do this, the acromion must become a fixed point, and that necessitates the contraction of the rhomboids and other muscles whose function it is, aided by the leverage afforded by the prolongation of the scapula downward, to fix the blade of the scapula when the deltoid is in action.

Superficial ecchymosis is rare on account of the dense infraspinous fascia which prevents the effused blood from reaching the surface.

Fracture of the acromion is attended with slight flattening of the tip of the shoulder, the weight of the arm, acting through the deltoid, dragging the fragment downward. There may be the usual symptoms of preternatural mobility, crepitus, etc.

Fracture of the coracoid is rare. Before the age of seventeen it may be an epiphyseal separation. Displacement is not common, as the downward pull of the pectoralis minor, short head of the biceps, and coraco-brachialis (page 590) is effectually resisted by the coraco-acromial and coraco-clavicular ligaments. Crepitus and preternatural mobility may possibly be recognized by sinking the fingers into the interval between the deltoid and pectoral muscles. The coracoid will be found just beneath the inner deltoid margin.

Fractures of the neck of the scapula include, in surgical language, those which begin at the suprascapular notch and run to the axillary border of the bone detaching the glenoid cavity and the coracoid process. There is no instance of fracture of the anatomical neck,—the constricted part supporting the glenoid cavity. The fragment, with the arm, will drop downward, away from the acromion. This puts the deltoid on the stretch and causes flattening of the shoulder. There will be a depression beneath the edge of the acromion. The arm will be increased in length. These symptoms (which will occur only if the coraco-acromial and coraco-clavicular ligaments are torn) are also found in subglenoid luxation of the humerus (page 583); but in the fracture, the presence of crepitus, the downward displacement of the coracoid, the ready disappearance of the deformity on pushing the head of the humerus upward, its prompt reappearance when the arm is allowed to hang by the side, and the ease with which the hand may be placed on the opposite shoulder serve clearly to denote the character of the accident.

Excision of the scapula itself is not uncommonly indicated on account of malig-

nant neoplasm, subperiosteal and central sarcomata especially. The main danger of the operation is hemorrhage. The subclavian should, therefore, be controlled. The dorsalis scapulæ, crossing the axillary border of the scapula at a point on a level with the centre of the vertical axis of the deltoid (Treves), and the subscapular running along the lower border of the subscapularis muscle to reach the inferior angle, are the largest vessels that require division, but the suprascapular, posterior scapular, and branches of the acromio-thoracic artery will also be cut.

Infectious diseases giving rise to caries and necrosis and to suppuration are rare. When they affect the supraspinous region the pus is directed forward by the fascia covering the supraspinatus, which encloses that muscle in an osseo-fibrous compartment. In the infraspinous region the still denser infraspinous fascia conducts the pus in the same direction; hence abscesses originating in scapular disease are likely to point near the axilla and in the neighborhood of the insertions of the scapular muscles into the humerus. On the under surface of the scapula, between the ridges which give origin to the tendinous fibres that intersect the subscapularis muscle, the periosteum is loose and easily separated. Suppuration following caries of this aspect of the bone may, therefore, cause extensive detachment of the periosteum, and it has been found necessary to trephine the thin portion of the blade of the scapula to give vent to such a purulent collection.

Landmarks.—The greatest breadth of the scapula is in a line from the glenoid margin to the vertebral border; the greatest length in a line from the superior to the inferior angle.

The general outlines of the scapula can easily be felt. The bony points most readily recognized by touch are the acromion, the coracoid, the spine, the vertebral edge, and the inferior angle.

The edge of the acromion is an important landmark. Measurement from it to the suprasternal notch is the easiest way of determining shortening in fracture of the clavicle. If this measurement is less than on the sound side, and the clavicle itself is unchanged in length, it indicates a dislocation of the acromial end of the latter.

Undue prominence of the edge of the acromion is seen in luxation of the humerus (page 582) and in fracture of the neck of the scapula. In these conditions the fingers may be pressed beneath the acromion, as they can in old cases of deltoid paresis or paralysis with atrophy of that muscle, when the weight of the arm drags the humerus downward and increases the space between the greater tuberosity and the acromial edge.

The coracoid process may be felt through the inner deltoid fibres, below the inner portion of the outer third of the clavicle, by thrusting the fingers into the space between the pectoral and deltoid. In fracture it may be depressed, as it is in fracture of the scapular neck. The axillary artery can be felt just to the inner side of the coracoid as it passes over the second rib.

The spine is least prominent in muscular and most conspicuous in feeble and emaciated persons. This is also true of the inferior angle, which in weak, and especially in phthisical, subjects is not held tightly to the chest, but projects in a wing-like manner (scapulæ alatæ). This is partly due to general muscular weakness, in which the latissimus dorsi and serratus magnus participate, and partly to the shape of the thorax and the direction of the clavicles. The flatter and shallower the chest the more oblique in direction and the lower are the collar-bones, carrying with them downward and forward the upper and anterior portions of the scapulæ, and by that much tending to make the lower and posterior portions more prominent.

The length of the arm is usually measured from the junction of the spine of the scapula and the acromion—the acromial angle—to the external condyle of the humerus.

The vertebral edge of the scapula lies just at the side of the spinal gutter. When the arm hangs at the side of the body, this edge is parallel with the line of the spinous processes. It can be made prominent (for palpation) by carrying the hand of the patient over the opposite shoulder. The superior angle is made accessible by the same position. The axillary border of the scapula and the inferior angle are best examined with the elbow flexed and the forearm carried behind the

back. With the arm at the side, the superior angle is about on the level of the upper edge of the second rib; the inferior angle is opposite the seventh intercostal space (and hence is a guide in selecting a space for the various operations for empyema, page 1867); the inner end of the spine is opposite the spinous process of the third dorsal vertebra.

With the shoulders drawn forcibly backward, the vertebral borders of the scapulæ can be made almost to touch at the level of the spines, and are not more than from two to three inches apart at the angles. With the hands clasped on the vertex, the inferior angles are from sixteen to seventeen inches apart. By crossing the arms on the front of the chest, and leaning forward, the scapulæ are also widely separated, and this position is therefore selected for auscultation and percussion.

The mobility of the scapula lessens the functional disability in ankylosis of the shoulder-joint.

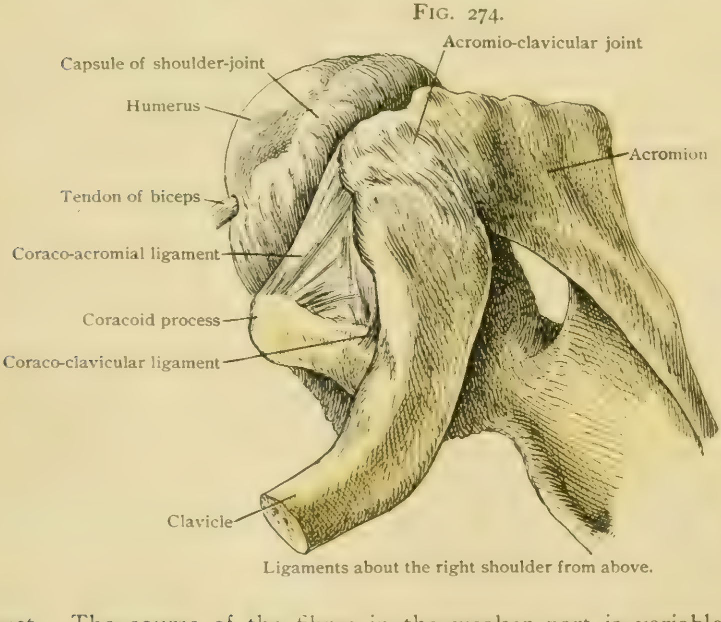
LIGAMENTS OF THE SCAPULA.

Two ligaments—the transverse and the coraco-acromial—pass from one part of the scapula to another.

The **transverse** or **suprascapular ligament**[1] (Fig. 289) is a little band on the upper border, just behind the root of the coracoid, making a bridge over the suprascapular notch, under which the suprascapular nerve passes. It may be replaced by bone.

The **coraco-acromial ligament**[2] (Fig. 274) is a triangular structure, broad at its base, along the outer border of the coracoid process, and narrowing to its insertion into the inner side of the end of the acromion just in front of the acromio-clavicular joint. The borders are strong, converging bands with a weak space between, the front one being the stronger and overlapping the other when they

FIG. 274.



Ligaments about the right shoulder from above.

meet. The course of the fibres in the weaker part is variable; sometimes they diverge from near the front of the coracoid to the posterior band, sometimes they are in the main parallel with the latter, sometimes a band passes from this membrane to the front of the clavicle. The weak portion of this ligament is pierced by the pectoralis minor, when, as often happens, this muscle is inserted into the capsule of the shoulder or the upper end of the humerus. This ligament is really part of the apparatus of the shoulder-joint, forming a roof over the capsule, from which it is separated by a bursa. Before dissection the hind border of the ligament is not very

[1] Lig. transversum scapulae superius. [2] Lig. coracoacromiale.

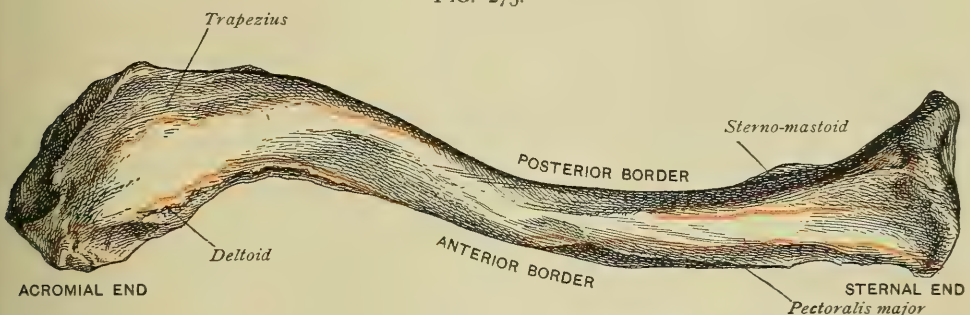
distinct, since the bursa appears to connect it with the capsule below and a thin fascia with the clavicle above.

The **spino-glenoid ligament**[1] is an occasional little band at the great scapular notch, running from the anterior border of the spine to the posterior edge of the glenoid cavity, crossing the suprascapular vessels and nerve.

THE CLAVICLE.

The function of the clavicle,[2] or collar-bone, which extends from the top of the sternum to the acromion, is to give support to the shoulder-joint in the wide and varied movements of the arm. It is found in mammals that climb, fly, dig, or swim with movements requiring an outward and backward sweep of the arm. It is absent in those that use the fore-limb simply for progression with movements nearly restricted to one plane. It is present, but imperfectly developed, in some carnivora

FIG. 275.

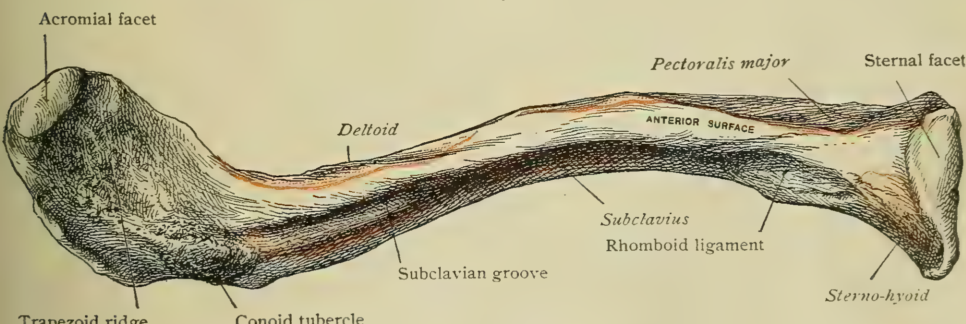


Right clavicle, superior and posterior surfaces.

whose arms serve, in part, for prehension. In man it has a doubly curved shaft, a thick inner end, and a flattened outer one.

The **shaft** is convex in front through the two inner thirds and concave in the outer one. The former portion has a superior, an inferior, an anterior, and a posterior surface; but in the outer third the two latter surfaces narrow into borders. The **superior surface** is smooth, except for a slight unevenness at the inner end,

FIG. 276.



Right clavicle, anterior and inferior surfaces.

giving origin to the clavicular head of the sterno-cleido-mastoid. The **inferior surface** has near the inner end an *oval roughness*, which may or may not be raised, for the rhomboid ligament from the cartilage of the first rib. Beyond this is a longitudinal *groove*, more marked near the outer end, for the insertion of the subclavius muscle. Outside of the middle, near the hind border (sometimes on the hind surface), is the *nutrient foramen*, directed outward. The **anterior surface** narrows continually from within outward. The inner two-thirds are rough for the pectoralis major;

[1] Lig. transversum scapulae inferius. [2] Clavicula.

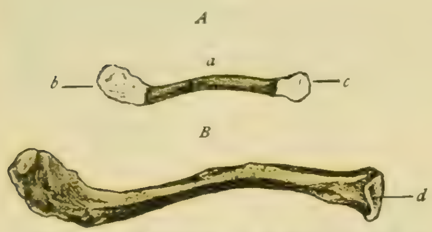
external to this the rough concave edge gives origin to the deltoid. The beginning of this is often marked by a minute tubercle, which, when exceptionally large, is the *deltoid tubercle*. The **posterior surface** is smooth, and narrows gradually till it reaches the outer end, the beginning of which is marked by a tubercle on the under surface.

The **borders** are very ill marked. The sharpest is that separating the anterior from the inferior surface. That between the anterior and superior ones is fairly well marked near the inner end ; but it soon grows indistinct, so that often at the middle of the bone the front surface seems to twist into the upper, and the anterior inferior border becomes the front border of the outer end. Of the posterior borders, the upper, though rounded, is distinct along the middle of the bone ; the lower is very vague, but usually is well defined in the outer part ; when it is not, the posterior surface seems to twist into the lower.

The **inner** or **sternal extremity**[1] is club-shaped, drawn out downward and somewhat backward. Its inner surface, coated with articular cartilage, is of very variable shape. It is approximately oval, with the long axis slanting downward and backward, and is rough and generally concave, but not always so. The front edge of the inner surface forms an acute angle with the anterior border of the bone, and the hind one an obtuse angle.

The **outer** or **acromial extremity**[2] is flattened above and below and curved forward. At the very front of this end is an articular surface joining the scapula. It is oval, with the long axis horizontal, and usually faces downward as well as outward. There is generally behind this a rough space for ligament at the end, which gradually slants into the hind border. The *conoid tubercle*[3] is at the posterior border of the lower surface of the outer extremity just at its junction with the shaft. The *trapezoid ridge* extends from it forward and outward across the bone. Its anterior portion is often broad. This tubercle and ridge are for the insertion of ligaments of corresponding names, passing upward from the base of the coracoid. Between the ridge and the end of the bone there is a smooth space, sometimes almost a groove, which lies above the supraspinatus muscle as it crosses the shoulder-joint. The clavicle varies greatly in length, thickness, amount of curve, and in the outline of the ends. Sometimes the outer end is but little broader than the shaft. A very rare form is one in which the inner part of the shaft is flat and but slightly thicker than the outer.

FIG. 277.



Ossification of clavicle. *A*, at birth ; *a*, chief centre ; *b*, *c*, cartilaginous ends. *B*, at about eighteen years ; *d*, sternal epiphysis.

Differences due to Sex.—The male bone is longer, stronger, more curved, and with larger articular facets. Apart from sex, a strong bone is generally more curved.

Development.—The centre for this bone, evident in the sixth week, precedes all others. It is remarkable as developing in indifferent tissue before any hint of the bone is to be seen. A little later a cartilaginous outline appears, which is shortly involved in the ossifying process. At about seventeen a centre is formed in the epiphysis at the sternal end, and joins the shaft a year or so later.

Surface Anatomy.—In life the anterior surface and edge, as well as the superior surface, are easily felt through the skin. The joint with the acromion is distinct, the clavicle being higher than the scapula. The position of the bone is nearly horizontal, but in strong men the outer end is often the higher. The bone is highly elastic, owing to its curves.

PRACTICAL CONSIDERATIONS.

The chief function of the clavicle is to steady the shoulder and keep the upper arm at such a distance from the trunk that the muscles running from the latter to the humerus may give it lateral motion. Therefore, in animals, in which no such

[1] Extremitas sternalis. [2] Extremitas acromialis. [3] Tuberositas coracoidea.

movement exists, and the fore-limbs are used only in progression, no clavicle, or a mere rudiment of it, is present.

Congenital absence of both clavicles is rare. In several reported cases the shoulders could be brought together in front of the body. The congenital absence of both acromial ends is not so uncommon. Theoretically, one would expect, as a result of absence of the clavicle, a weakened upper extremity, some lateral curvature of the spine, interference with the upper chest (from the weight of the arm and scapula), and hence diminished lung capacity with the secondary ill effects upon growth, nutrition, etc.

Such consequences were predicated (Maunder) as a result of arrest of growth from epiphyseal separation, but neither in those cases, in non-union after fracture, nor in congenital absence have they been noted. On the contrary, in the four cases of symmetrical absence of the acromial end recorded by Gegenbaur the functional disability was slight, the motions of the scapula being unimpaired.

The whole bone becomes ossified very early, beginning before any other long bone of the skeleton. Its one epiphysis, at the sternal end, is, on the contrary, the last of the epiphyses of the long bones to ossify, appearing about the seventeenth or eighteenth year and, according to Poland, joining the diaphysis from the twenty-second to the twenty-fifth year. Dwight places the time of union somewhat earlier.

Separation of this epiphysis is among the rarest of epiphyseal detachments. But five cases have been recorded. Two of them were from muscular action, the pectoralis major and the clavicular fibres of the deltoid being apparently the agencies that carried the sternal end of the diaphysis forward.

The age of the patient (from seventeen to twenty-five), the shape of the flattened diaphyseal end (unlike the pointed end of a fractured bone), and the integrity of the shape of the suprasternal notch aid in distinguishing this accident from a forward dislocation or a fracture on the inner side of the costo-clavicular ligament.

Fracture of the clavicle is more common than that of any other bone, except possibly the radius ; it is, likewise, the most frequent seat of incomplete ("greenstick") fracture. About one-half of all clavicular fractures occur during early childhood. This frequency is due (1) to the early ossification of the bone, so that it is relatively more brittle than are the other bones ; (2) to the lack of close attachment between the periosteum and the bone ; (3) to the unusual thickness of the periosteum (probably associated with the early ossification), which tends to prevent complete fracture ; and (4) to the common occurrence of falls and minor accidents among children.

The amount of disability is often surprisingly slight, and the diagnosis, unless confirmed by skiagraphic testimony, may have to be made on the basis of very trifling deformity with localized tenderness and swelling.

Muscular action may produce fracture through the violent contraction of the pectoralis major or of the clavicular portion of the deltoid.

Indirect violence (received through falls on the hand, elbow, or shoulder) is the common cause. The frequency with which such falls occur, and the uniformity with which the force is transmitted to a slender bone containing but little cancellous tissue, and held firmly at either end by strong ligamentous attachments, sufficiently explain the common occurrence of clavicular fracture.

The break usually occurs about the junction of the middle and outer thirds, because: (1) the outer end (like the inner) is firmly held by the ligamentous connections, the middle of the bone being the most movable ; (2) at the outer end of the middle third the bone is smaller, and therefore weaker ; (3) at this point the sternal curve (convex forward) and the acromial curve (concave forward) meet, and force applied to the extremity of the bone is there expended.

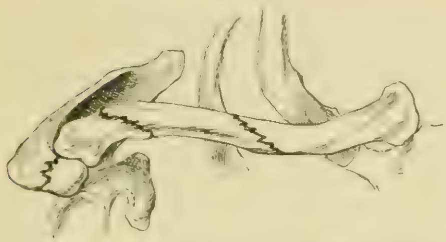
Fracture of the clavicle is rarely compound, because, although the bone is subcutaneous, the skin is very freely movable over it, and because the usual displacement carries the sharp end of the outer fragment backward and the sharp end of the inner fragment upward (Fig. 278).

The anatomical causes of the common form of displacement will be considered in connection with the muscles concerned (page 579).

The relations of the clavicle to great vessels and nerve-trunks would seem to render frequent complications probable, but as a matter of fact the latter occur with

comparative rarity : (1) because of the elastic curves of the bone, which enable it to escape fracture in many cases of direct violence ; (2) because of the interposition of the subclavius muscle between the bone and the nervous and vascular trunks ; (3) because of the situation of the common fracture, the inner end of the outer fragment (the portion most likely to inflict injury) being both above and external to the region of danger. Still, cases of wound of the subclavian vessels, internal jugular vein, and of pressure paralysis of the upper extremity have been reported as complications of fracture of the clavicle.

Fig. 278.



Lines of fracture of the clavicle and acromion process.

The supraclavicular nerves (branches of the third and fourth cervical) pass in front of the bone, and may be involved in the callus, giving rise to severe and persistent pain.

In *resection* or *excision* of the clavicle, either for disease or as a step in the performance of an interscapulo-thoracic amputation, the protection afforded the vessels by the subclavius muscle should be remembered. Superficially, the cephalic vein and the supraclavicular nerves may have to be divided.

Disease of the clavicle is not uncommon as a result of the various infections,—syphilitic, tuberculous, typhoidal, etc. The bone is also the subject of new growths, especially of sarcomata. The anatomical relations already alluded to are those chiefly involved in these cases.

Swelling and œdema of the arm may result from pressure on the subclavian vein in the angle between the clavicle and the rib ; gangrene, from pressure upon the artery ; pain or paralysis, from pressure upon the brachial plexus at the outer part of the costo-clavicular space. It is probable that, in view of the subcutaneous position of the clavicle and its consequent exposure to slight traumatisms, osteitis of one form or another would be more frequent if it were not for its great elasticity, which probably limits the effect of minor blows to the superficies of the bone. Accordingly, syphilitic subperiosteal nodes are fairly common, while tuberculosis and septic and post-typhoidal osteitis are relatively rare.

Landmarks.—The clavicle is subcutaneous through its entire length. When at rest the bone is about on the same level as the spine of the scapula. In inspiration it moves forward an inch.

The inner end of the bone is its largest portion, and its projection in front of and above the clavicular notch on the sternum should not be erroneously regarded as evidence of disease or injury. The deltoid tubercle at its outer third is sometimes unusually prominent, and should not then be mistaken for an exostosis.

The curves of the bone may easily be traced from end to end. The normal curves may be increased in greenstick fracture without any positive angularity being produced ; but in this case careful measurement will show that the distance between the two ends of the bone is slightly lessened as compared with the uninjured side. It should not be forgotten, however, that the curves are apt to be increased in muscular persons, and that for the same reason the right clavicle is sometimes more curved, thicker, and a little shorter than the left.

In general terms it may be said that the inner third of the bone is in relation below to the first rib, which it crosses obliquely ; the middle third to the axillary vessels and the brachial plexus (and below them to the first intercostal space); and the outer third to the coracoid process and the acromio-clavicular joint (Fig. 274). In the male, and in robust, vigorous persons generally, the clavicles are on a high plane and pass almost horizontally outward, giving the "square-shouldered" appearance usually associated with ideas of muscular strength and decreasing the apparent length of the neck. In the strong male the outer end may even be higher than the inner.

In narrow-chested and in consumptive persons the clavicles are depressed and

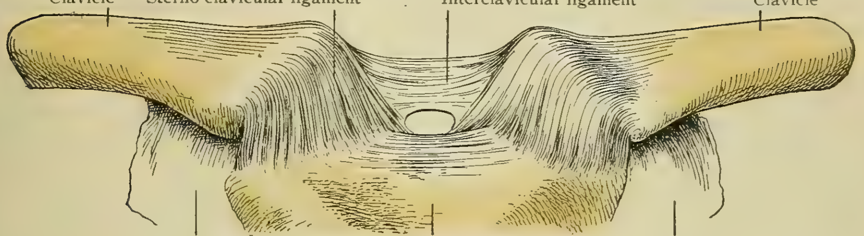
incline downward, and hence the sloping narrow shoulders and long necks so often seen in feeble or in phthisical individuals.

In very fat persons, in those suffering from organic heart disease attended with dyspnœa, and in emphysematous subjects the clavicles are raised and the neck thereby apparently shortened.

THE STERNO-CLAVICULAR ARTICULATION.

This is the only joint between the trunk and the upper extremity. The socket on the upper angle of the manubrium is coated with cartilage which often extends a little onto the first costal cartilage. This very shallow socket is made rather more secure by the forward inclination of the manubrium and also by being rather

FIG. 279.

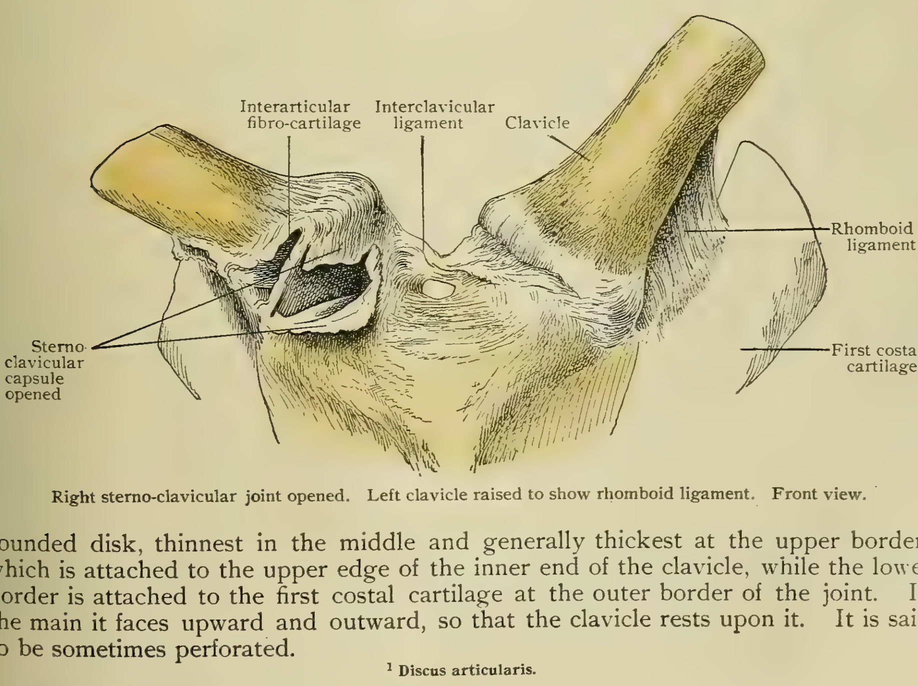


Sterno-clavicular articulations from before; clavicles horizontal.

more on the back than on the front of that bone, so that to some extent it overlaps the front of the clavicle. The very irregular end of the clavicle is coated with cartilage, which, however, gives it no regular nor constant shape. As a rule, it is concave from before backward, but there is often a swelling at the posterior lower angle.

The **interarticular fibro-cartilage**[1] (Fig. 280), a disk subdividing the joint into two, is the chief factor in maintaining the great security of the joint. It is a

FIG. 280.



Right sterno-clavicular joint opened. Left clavicle raised to show rhomboid ligament. Front view.

rounded disk, thinnest in the middle and generally thickest at the upper border, which is attached to the upper edge of the inner end of the clavicle, while the lower border is attached to the first costal cartilage at the outer border of the joint. In the main it faces upward and outward, so that the clavicle rests upon it. It is said to be sometimes perforated.

[1] Discus articularis.

The **capsule** (Fig. 280) surrounds the joint, being attached to the borders of the articular surfaces and also to the borders of the interarticular disk. It is strengthened before and behind by bands running upward and outward from the sternum, of which the posterior are the stronger, and sends some deep fibres to the disk. These bands strengthening the capsule are sometimes described as the *anterior* and *posterior sterno-clavicular ligaments*. There are two distinct *synovial cavities*.

The **interclavicular ligament** (Fig. 279) is a fairly well-defined band running from the top of one clavicle across to the other. It is closely connected with the top of the joint and loosely with the top of the sternum, towards which it sinks with a slight curve. This does much towards filling up the deep interclavicular notch.

The **costo-clavicular**[1] or **rhomboid ligament** (Fig. 280) arises from the costal cartilage just outside of the joint, with which it is loosely connected, and runs upward and outward to the rough rhomboid impression on the under side of the clavicle. It is a layer of strong, short fibres.

THE SCAPULO-CLAVICULAR ARTICULATION.

The Acromio-Clavicular Articulation.—This joint includes a capsular ligament (Fig. 274) and occasionally an intra-articular fibro-cartilage. The elongated facet on each bone is covered with articular cartilage, that of the clavicle usually overlapping the other.

The **capsule** is weak, except above and behind, where there are strong bands extending outward from the clavicle. Of these the posterior are the longer.

The **fibro-cartilage**, when present, is wedge-shaped, attached by the base to the superior part of the capsule, the thin edge reaching, perhaps, half-way through the cavity of the joint. Sometimes it divides the joint into two. There may be merely a thick pad of fibrous tissue attached to the outer end of the clavicle with only a very rudimentary joint.

The **coraco-clavicular ligament** is an important ligamentous apparatus divided into an outer part, the *trapezoid*, and an inner, the *conoid* (Fig. 289). These are continuous behind, but diverge in front. The **trapezoid ligament**[2] is a four-sided layer of parallel fibres, springing from the trapezoid ridge and the top of the first part of the coracoid, to run outward to the trapezoid ridge on the under side of the clavicle. The line of attachment to the clavicle is usually the longer, and, as this runs forward and outward, the anterior fibres are almost horizontal. The **conoid ligament**,[3] or inner part, is less strong. It arises from the posterior border of the conoid tubercle at the root of the acromion, and runs to the tubercle of the same name at the back of the under side of the clavicle. Both these tubercles being prominences of some size, this ligament is not a cord, as might be inferred, but another layer continuous with the trapezoid behind. The inner fibres incline inward as they ascend. The general direction is upward and perhaps a little backward, but this changes with the position of the bones. There may be a synovial bursa in the open angle seen from the front between these two parts of the ligament.

Movements of the Clavicle and Scapula.—The compound joint at the inner end of the clavicle is practically a universal one. The clavicle can be raised, depressed, carried forward or backward, circumducted, and slightly rotated. The outer and lower end of the disk being attached to the corresponding border of the facet, it follows that the clavicle lies upon it. When the shoulder is raised or depressed the motion is almost wholly between the clavicle and the disk, though the latter slides a little, and in marked falling of the shoulder the top of the disk starts to come out of the socket, but is restrained by the top of the capsule. Forward and backward motions occur chiefly between the disk and the sternum, but there is some displacement of the former. Circumduction, therefore, involves both parts of the joint; rotation is chiefly in the inner one.

It is remarkable that a joint at which there is so much strain, owing to leverage, should be so strong with such apparently imperfect bony arrangements for retention. Part of the safety is due to the subdivision of the joint and a great deal to the assistance of muscles. At both ends of the clavicle, as Morris has pointed out, the great muscles are so placed that by their contraction they draw the bones together.

[1] Lig. costoclaviculare. [2] Lig. trapezoideum. [3] Lig. conoideum.

The obvious advantage of a joint between the clavicle and the acromion, apart from breaking shocks and making the shoulder-girdle much more elastic, is that it allows the angle between the bones to change with the position of the arm, and thus the direction of the glenoid cavity may be modified so as to give the best support to the arm in different positions. The motion at the outer end of the clavicle is considerable, but indefinite. The overlapping clavicle can advance a little laterally onto the acromion, except in the cases in which the plane of the joint is vertical. There is also motion on an approximately vertical axis when the shoulder is thrown forward and the outer end of the clavicle advances, the angle between the back of the clavicle and the spine of the scapula being diminished. When the clavicle can advance no farther, the tension of the trapezoid ligament checks the progress of the coracoid. In the withdrawal of the shoulder the reverse occurs, the movement being finally checked by the conoid. In up-and-down movements of the shoulder the motion is on an approximately antero-posterior axis. When it rises the base of the coracoid comes into direct contact with the clavicle and the rhomboid ligament is strained ; when it falls the clavicle rests on the first rib and the conoid is put on the stretch, as are also the interclavicular ligament and the top of the capsule of the sternal end. Probably the freest movement is when the arm is raised vertically, in which case the lower angle of the scapula swings strongly forward so as to direct the glenoid cavity more nearly upward. The clavicle rises from the sternal end, and perhaps slightly rotates. Possibly the lower end of the scapula is withdrawn slightly from the chest. Apart from the movements of the arm the scapula may change its position considerably. It may rotate on either the end of the acromion (as in raising the arm) or on the superior angle, the lower angle being the most movable point. When it is carried far forward a larger portion of the posterior surface of the lungs can be examined. The scapulæ may also be raised or brought nearer together.

Surface Anatomy of the Shoulder-Girdle.—The general shape of the clavicle is easily made out by pressing on its front and superior surfaces with the muscles relaxed. The degree of backward projection of the inner end can be determined. It is placed horizontally in woman ; in man the outer end is slightly raised. The joint with the acromion is easily felt from above, the clavicle being the higher. The outline of the acromion, which slopes somewhat downward, is easily felt. It forms the point of the shoulder-girdle, but not of the shoulder, as the humerus always projects beyond it externally. A plane vertical surface placed against the outside of the shoulder cannot touch the acromion if the head of the humerus is in place. The possibility that the outer epiphysis of the acromion may not unite by bone is to be remembered. The finger can be carried from the acromion along the spine to its triangular origin. The tip of the coracoid is to be felt by manipulation in the infraclavicular fossa at the inner side of the humerus. The posterior border of the scapula is always to be felt ; in thin persons its outline can be traced and the shape of the inferior angle approximately recognized.

PRACTICAL CONSIDERATIONS.

The Sterno-Clavicular Articulation.—The interposition of an elastic buffer in the shape of the interarticular fibro-cartilage, united to both the bones by very strong ligamentous fibres, and completely bisecting the joint (Fig. 280), in fact, converting it into two separate joints, prevents the clavicle from transmitting to the sternum the full force of blows and falls received upon the hand or shoulder, and allows of the varied, though limited, movements of the articulation.

Dislocation is rare. The ligaments are stronger than the clavicle, which is therefore usually broken by any force sufficient to threaten the integrity of the joint. The curves of the clavicle, the mobility of the scapula, and the play of the acromio-clavicular joint all tend to diffuse forces that might otherwise have been expended on this articulation, which is furthermore strengthened by the tendinous origins of the sterno-cleido-mastoid and of the pectoralis major.

The most common form of dislocation is the forward one, the anterior sterno-clavicular ligament being the weaker and thinner. Backward luxation is re-

sisted by the more powerful posterior ligament and by the rhomboid. Upward displacement—the least frequent—is resisted by the interarticular cartilage, which is strongly inserted below into the cartilage of the first rib and the sternum, and above into the clavicle itself, by the rhomboid and interclavicular ligaments and by both the anterior and posterior ligaments ; hence the rarity of this luxation.

In many displacements of the sternal end of the clavicle the shoulder is carried downward or backward until the clavicle is in contact with the strong first rib, which then acts as a fulcrum, the sternal end of the bone continuing its upward or forward motion until the resisting ligaments are torn and the luxation is produced.

In backward dislocation by indirect violence the force has usually pushed the shoulder forward and inward, as when the patient has been caught between two cars or between a wall and a wagon.

In this dislocation the sternal end may press upon the trachea, the internal jugular, or the beginning of the innominate vein, and may therefore, if the faulty position has become permanent, require excision.

Disease of the sterno-clavicular joint is not very common, considering its superficial position and its constant motion. This is probably due to the fact that the motion is slight and that strains and injury to the synovial membranes are prevented by the strong and elastic interarticular cartilage and by the strength of the ligaments. Suppuration usually shows itself in front (as the anterior ligament is the thinnest), but may perforate by ulceration the posterior ligament and find its way to the mediastinum. With the arm at the side the articulation becomes V-shaped, the clavicle touching the joint surface only at its lowest angle. With the arm elevated, the two joint surfaces are brought into closer relation, and the shape of the joint viewed from the front becomes linear ; hence raising of the arm is uniformly productive of pain in disease of the joint.

Ankylosis is rare, probably owing to the separation of the diseased joint surfaces by the thick, resistant fibro-cartilage.

The Acromio-Clavicular Articulation.—This is one of the shallowest of the articulations, the clavicle being merely superimposed, as it were, upon the upper edge of the acromion. The powerful ligaments which bind the clavicle to the coracoid (the conoid and trapezoid), although they have no direct relation to the joint, are the most important factors in preserving its integrity when force is applied to the point of the shoulder.

The movements of the joint are around two axes, an antero-posterior and a vertical one, so that the relations of the glenoid cavity to the humerus may remain relatively unchanged when the arm is elevated or is advanced. The scapula must obviously move backward or forward on the side of the chest in a curve established by the curve of the ribs. It does this on a radius represented by the clavicle, the centre of the rotation being at the sterno-clavicular joint. The acromio-clavicular joint enables this motion to take place, while at the same time the glenoid cavity continues to point obliquely forward. If it were not for this, the act of pushing or striking with the arm advanced, or of falling upon the hand with the arm in a like position, would bring the head of the humerus against the capsule of the joint instead of against the glenoid cavity, and would thus increase the frequency of luxation. Conversely, "rigidity of this little joint may be a cause of insecurity in the articulation of the shoulder and of weakness in certain movements of the limb" (Treves).

Dislocation is rare. The dislocation of the acromial end of the clavicle upward (described by some surgical writers, for the sake of uniformity, as dislocation of the scapula downward) is much the more frequent. The capsular ligament is torn or stretched, even in the incomplete forms. In the complete variety the coracoclavicular ligaments must be torn or ruptured, but their great strength, increased in effectiveness by their distance from the joint, renders this accident uncommon.

Dislocation of the clavicle beneath the acromion—between it and the coracoid process—and dislocation of the clavicle beneath the coracoid are extremely rare accidents. It is not certain that the latter has ever occurred. Both obviously require for their production extensive laceration of all of the ligaments binding together the scapula and the outer portion of the clavicle.

THE HUMERUS.

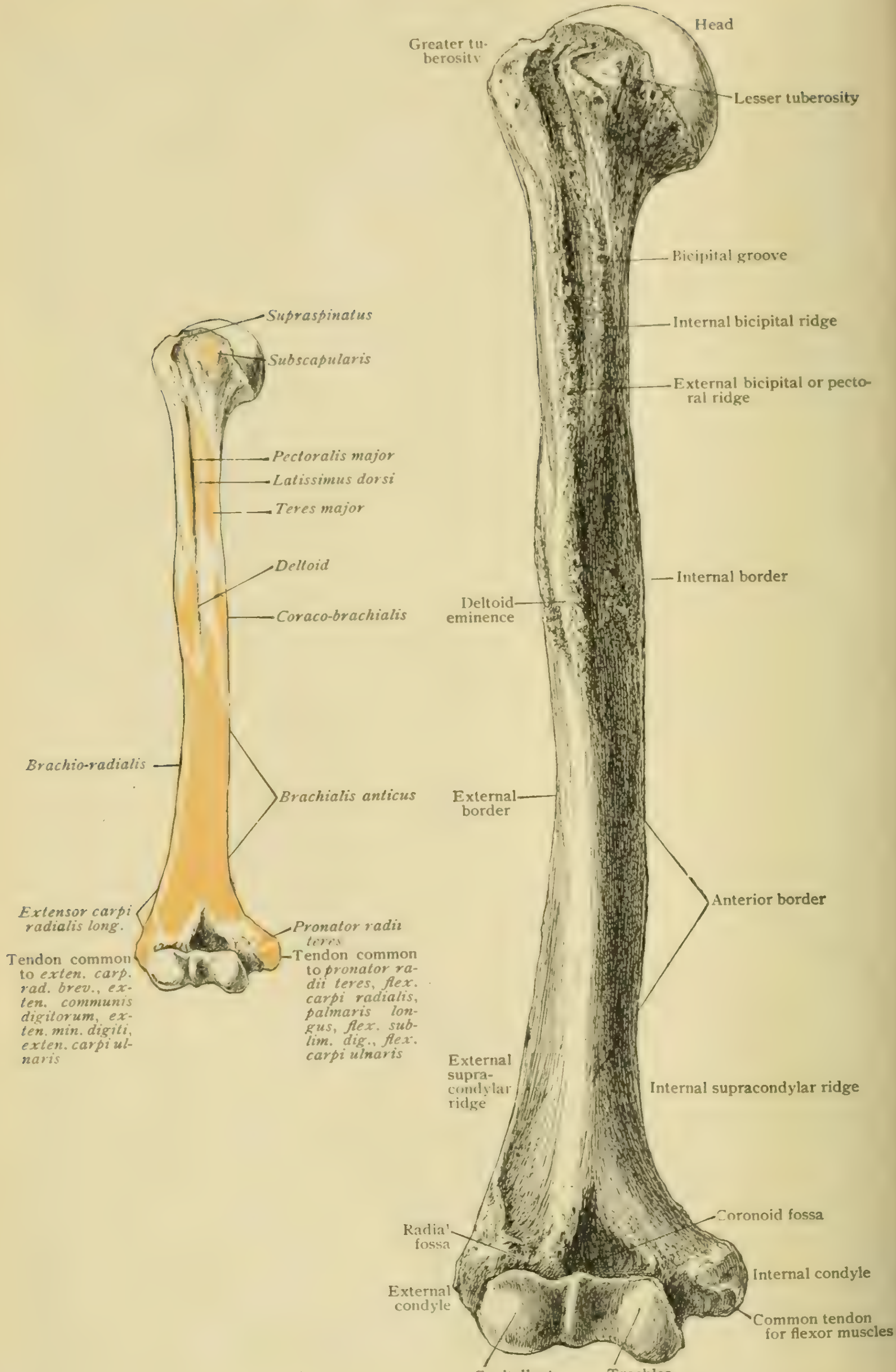
The bone of the arm consists of a shaft and two enlarged extremities.

The **upper extremity** includes a globular articular *head* and two *tuberosities* for muscular insertions. The **head**[1] looks upward, inward, and backward. It is not truly a part of a sphere, for the curve in the horizontal plane is bolder than that in the vertical. The vertical diameter between the edges of the articular surface is longer than the transverse. It is surrounded by a slight groove for the attachment of the capsular ligament at what is called the *anatomical neck*.[2] The *surgical neck*[3] is just below the whole upper extremity. The tuberosities are separated in front by a deep furrow, the *bicipital groove*,[4] through which runs the tendon of the long head of the biceps. The **greater tuberosity**[5] is a rough enlargement placed externally. Its highest point is at the front, just by the groove. A superior surface of this tuberosity begins here and, passing downward and backward beside the head, broadens as it goes. It bears three smooth *facets* for the insertion of the supraspinatus, the infraspinatus, and the teres minor, in this order ; the first being highest and most in front, the last and lowest most behind. The **lesser tuberosity**,[6] much smaller, is on the front of the bone. It bears a prominent angle, sometimes an actual crest running downward and inward for the subscapularis. The upper aspect of the process, which looks also inward, is smooth for a bursa beneath the tendon.

The **shaft** is roughly cylindrical above and prismatic below. It is convenient to divide it by three borders into three surfaces. The *anterior border* starts from the greater tuberosity as the outer lip of the bicipital groove, which, growing shallower, can be traced through the first quarter of the shaft. This outer lip becomes thicker and more prominent for some two inches below the surgical neck to receive the insertion of the pectoralis major. Below this it is joined by the lower end of the deltoid eminence, after which, smooth and rounded, it grows fainter, but may be traced downward to a ridge separating the capitellum from the trochlea, where it ends. The *internal border* starts at the inner side of the neck, often so near the inner lip of the bicipital groove as to be confounded with it, and runs straight down to the very tip of the internal condyle. It is at best very faint in the first quarter, and often barely visible ; but it is distinct in the middle and prominent in the last third, where it is known as the *internal supracondylar ridge*. The *external border* begins at the back of the greater tuberosity and runs to the outer condyle, the lower part being the *external supracondylar ridge*, which has a forward curve. A great exaggeration of this ridge has been seen in the negro. The *internal surface* bears the inner lip of the bicipital groove, which, starting from the lesser tuberosity, is often very faint ; it receives the tendon of the teres major. The bicipital groove soon becomes shallow, and is lost after two or three inches. The *nutrient foramen*, running downward into the bone, is rather below the middle of this surface, sometimes being almost in the internal border. The *external surface* is convex in the upper half and concave in the lower. Its second quarter is occupied by a long, rough elevation, the *deltoid eminence*,[7] slanting downward and forward against the inner border for the insertion of the deltoid muscle. The *posterior surface* is twisted, facing somewhat inward above and backward below. The upper plane portion gives origin to the outer head of the triceps, and the lower, convex except below, to the inner head. A broad *spiral groove* beginning on the external surface behind the deltoid eminence, in front of the outer border, twists forward and downward. This is generally improperly called the *musculo-spiral groove*.[8] The groove truly deserving that name, containing the musculo-spiral nerve and the superior profunda artery, occupies the lower and posterior part of the greater groove, from which it usually is not to be distinguished throughout, though both grooves may be distinct. The musculo-spiral groove is some five millimetres broad, and, when well developed, begins on the posterior surface, separating the areas for the outer and inner heads of the triceps muscle, and interrupts the external border, behind which the broad spiral groove never passes. A second nutrient foramen, also running downward and sometimes the larger of the two, may occur in the groove. The shaft takes a forward bend just at its termination, so that most of the lower end lies in front of the continuation of the axis of the shaft.

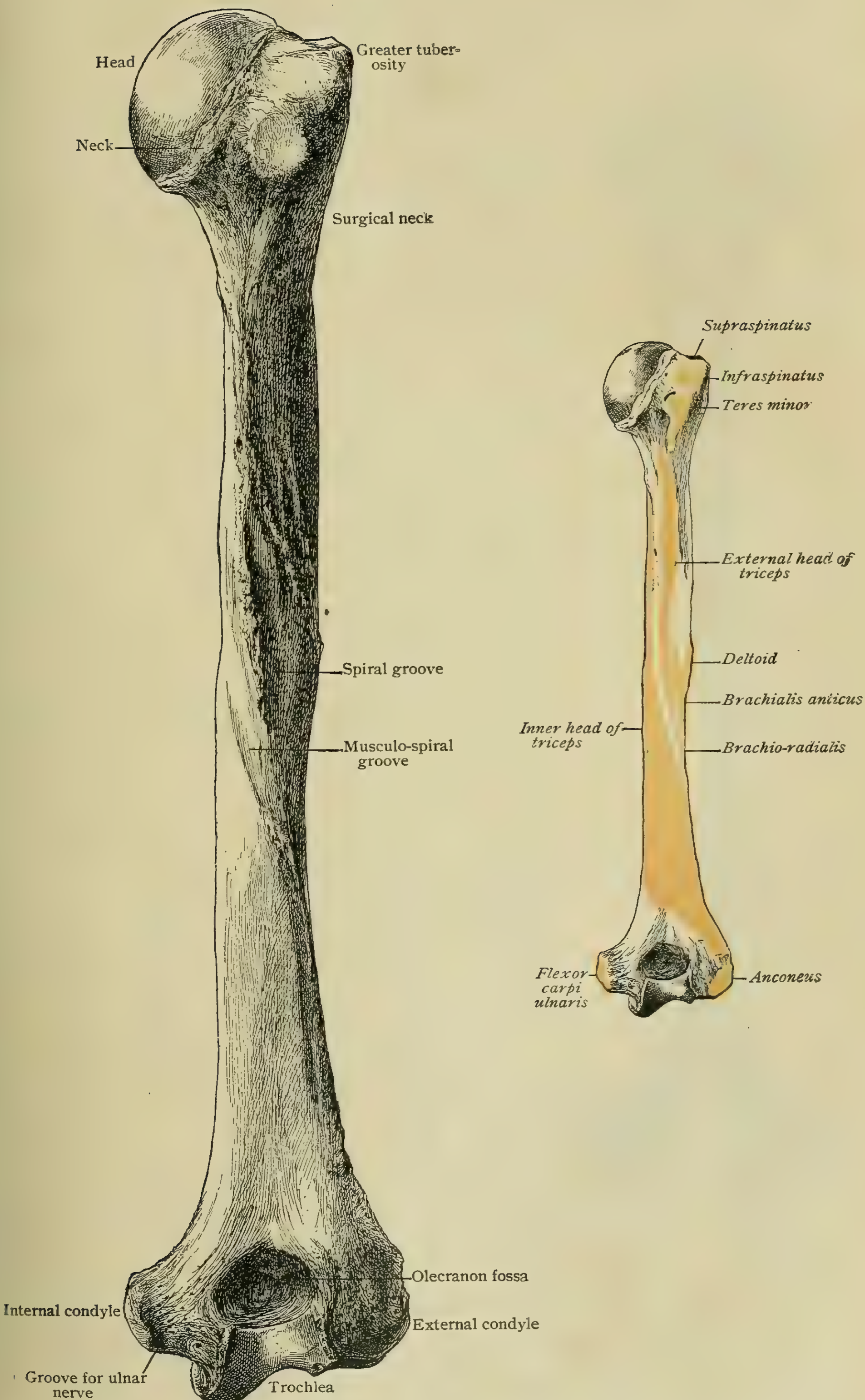
[1] Caput humeri. [2] Collum anatomicum. [3] C. chirurgicum. [4] Sulcus intertubercularis. [5] Tuberculum majus. [6] Tub. minus. [7] Tuberositas deltoidea. [8] Sulcus radialis.

FIG. 281.



Right humerus from before. The outline figure shows the areas of muscular attachment.

FIG. 282.



Right humerus from behind. The outline figure shows the areas of muscular attachment.

The **lower extremity** is broad from side to side, with an articular surface below, and two lateral projections, the *condyles*. The *inner condyle*,[1] much the larger, is sharp and prominent, giving rise with a part of the supracondylar ridge to the flexor pronator muscles. It is faintly grooved behind by the ulnar nerve, and the lower part of the front often presents a smooth surface. The *outer condyle*[2] is a slightly raised knob. The articular surface, most of which is at a lower level than the condyles, consists of two parts,—an inner pulley-like surface, the *trochlea*, for the ulna, and an outer convexity, the *capitellum*, for the radius.

FIG. 283.

Longitudinal section of humerus, showing relation of compact and spongy bone.

The **trochlea**[3] is bounded internally by a sharp border, forming about three-quarters of a circle, and projecting below the rest of the bone as well as before and behind it. It is bounded externally by a ridge, which is prominent behind where the trochlea forms the whole of the articular surface, but is faint in front where it separates the trochlea from the capitellum. Above the joint this ridge is continuous with the anterior border of the shaft.

The trochlea is convex from before backward. A section through the middle forms almost a complete circle, being broken only above, where a thin plate connects it with the shaft. It is concavo-convex from side to side, the convexity being greatest at the inner border. There is a depression above the trochlea both before and behind; the former, the *coronoid fossa*, is small and receives the coronoid process of the ulna in flexion; the posterior depression, triangular and much the larger, is the *olecranon fossa*, receiving that process in extension. The bone separating these fossæ—the plate just alluded to—is so thin as to be translucent. It may be perforated by the *supratrochlear foramen*, most frequently found in savage tribes. The joint between the humerus and ulna is commonly called a hinge-joint, but there are serious modifications. First, the axis of the trochlea is not at right angles to that of the shaft, but slants downward and inward; next, the borders of the trochlea are not at right angles to its axis, but are so placed as to transform it into a spiral or screw-joint; finally, these borders are not parallel to each other, but the inner slants downward and inward so that the transverse diameter of the joint is greater below than at the top, either before or behind.

The **capitellum**,[4] on which the concave head of the radius plays, is situated on the front of the outer part of the lower end. It is not far from being a portion of a sphere, since it is convex and nearly equally so in all directions, but the arc from above downward is the longest. A groove runs between it and the outer ridge of the trochlea; the outer border is straight; the posterior runs from it obliquely backward and inward. The capitellum is placed so much to the front as to be nearly or quite invisible from behind; hence the articular surface is much more extensive on the front than the back. The *radial fossa*, a small depression above the capitellum, receives the edge of the head of the radius in extreme flexion.

The *supracondylar process* is a small bony spur occurring in probably two or three per cent., which arises from the front of the bone a little anterior to the

[1] Epicondylus medialis. [2] Epicondylus lateralis. [3] Trochlea. [4] Capitulum.

internal supracondylar ridge. It is usually connected by a fibrous band to the tip of the inner condyle, thus representing the supracondylar foramen found very generally among mammals. The median nerve and generally either the brachial or the ulnar artery pass through it. The process, without any completing ligament, has been seen hooking over the nerve alone. We have once seen a bony foramen.

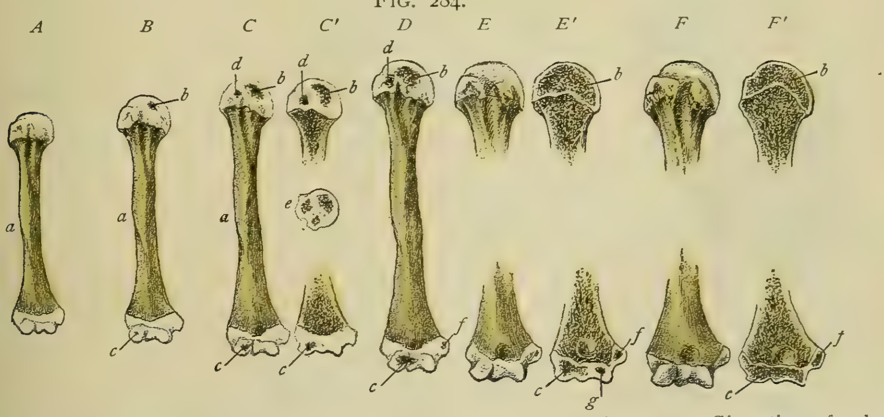
The so-called **torsion of the humerus** is a very complicated problem arising from the theory of the changes necessary to account for the adult condition of the humerus and femur, assuming them to have been originally symmetrical. The practical point is that the horizontal axis subdividing the articular surface of the head of the humerus, imagined on the same plane as the transverse axis of the elbow, forms an angle with the latter. This angle varies considerably; according to Gegenbaur, it is 12° for the adult European. In the lower races it is greater, and still greater in the lower animals. (This is what Continental anatomists call the *supplemental angle*, as they assume that the twisting has approached 180°, and that thus the true angle is 168°. We give this as the simplest.) The angle is greater in the fœtus. Gegenbaur gives it as 59° at from three to four months, and as 34° at from three to nine months, after birth. This change probably occurs in the epiphyses. It is certain that the shaft of the developing humerus does not actually twist, for the borders are straight, as are all the long nerves with the single exception of the musculo-spiral. No spiral fibres have been found in the bone.

Structure.—The walls of the shaft are of compact bone enclosing a cavity. At the upper end the head is made of round-meshed tissue of considerable density; the greater tuberosity is of lighter structure; both are enclosed by thin bone. The line of union of the upper epiphysis is seen on section after it has disappeared from the surface. Transverse sections at the lower end show a system of strong plates passing obliquely from the front to the back above the inner condyle.

Differences due to Sex.—The chief guides are the greater delicacy of the female bone, and especially the smaller size of the head. It is generally thought that the female humerus presents a sharper angle between the axis of the shaft and the transverse axis of the trochlea than does the male, but Berteaux's[1] measurements make the difference too slight to be significant,—79° for man and 78° for woman.

Development.—The primary centre for the shaft appears towards the end of the second fœtal month, and before birth bone has reached to the extremities, which are formed by the union of several centres. There are two or three for the upper, a chief one for the head coming soon after birth and sometimes earlier. It is

FIG. 284.



Ossification of humerus. *A*, just before birth; *B*, in the first year; *C*, at three years; *C′*, sections of ends of preceding; *D*, at five years; *E*, at about thirteen years; *E′*, sections of ends of preceding; *F*, at about sixteen; *F′*, sections of ends of preceding. *a*, centre for shaft; *b*, for head; *c*, for capitellum and part of trochlea; *d*, for greater tuberosity; *e*, for head and tuberosities in transverse section; *f*, for internal condyle; *g*, for inner part of trochlea.

present at birth in 22.5 per cent. of fœtuses weighing seven pounds and over (Spencer[2]). It is almost always present by the end of the third month after birth. In the third year ossification begins in the greater tuberosity, and another point may appear somewhat later in the lesser one. At five all the centres for this end have

[1] Le Humerus et le Femur, Paris, 1891.
[2] Journal of Anatomy and Physiology, vol. xxv., 1891.

become one, making a cap for the top of the shaft, which latter extends into the head. The largest centre for the lower end is that for the capitellum, which is seen by the end of the first half-year. It forms also a part of the outer side of the trochlea. A centre for the tip of the inner condyle is evident by the fifth year. One or more minute points of ossification for the trochlea appear in the tenth year, and one for the tip of the external condyle in the fourteenth. Although all these epiphyses are originally in the same strip of cartilage, they do not unite into one piece of bone. The capitellum is joined by the ossification for the trochlea, and joins the shaft at from fourteen to fifteen. We are not sure whether the insignificant centre for the outer condyle, which fuses at about the same time, joins the epiphysis or the shaft. Rambaud and Renault seem to believe the latter. The centre for the internal condyle remains separate after the rest are fused and joins the shaft at about eighteen. The upper end joins at about nineteen, the line of union being lost at twenty or twenty-one. It is usually lost earlier in the female.

Surface Anatomy.—The external and internal condyles are the only points that are truly subcutaneous. The outer is easily recognized under normal conditions, but is quickly obscured by swelling. The internal is so prominent that it can always be recognized, unless the joint has been utterly broken to pieces. The fact that the inner condyle joins the shaft after the rest of the lower end exposes it to the danger of being broken off before the union has occurred, or while it is still weak. The upper end of the humerus is everywhere covered by muscle, but much of its outline can be explored. The amount of its forward projection varies much ; but it always projects outward beyond the acromion. The lesser tuberosity and the bicipital groove can be recognized on rotating the bone, but indistinctly. The groove is filled by the tendon and still further obscured by the capsule and muscles. The surgical neck is best felt in the axilla, whence, the arm being extended, the head can be examined, though imperfectly.

PRACTICAL CONSIDERATIONS.

The humerus occasionally fails to develop, either alone or together with the other bones of the extremity. The bone of one arm may be shorter and thicker than the normal bone. Lengthening beyond normal limits is much rarer.

Fig. 285.

Fracture of anatomical neck of humerus, showing impaction.

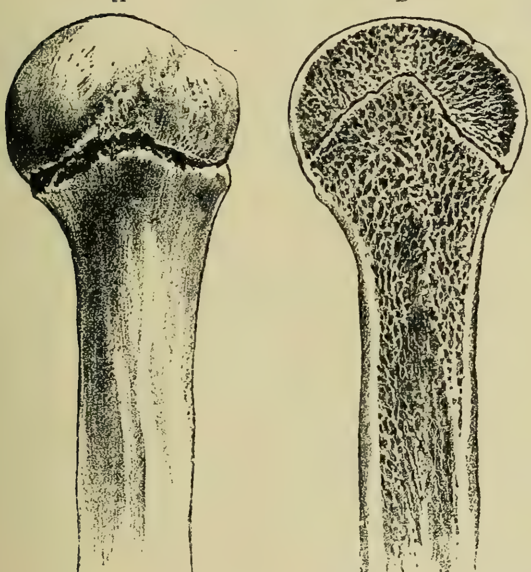
The shallowness of the glenoid cavity obviates the necessity for projecting the head of the bone from the shaft, as in the femur ; the "neck" is, therefore, merely a very narrow and superficially shallow constriction of an inward prolongation of the shaft between the tuberosities below and the joint surface above. Both its shortness and its shallowness render it far less liable to fracture than the femoral neck. When, in old age, absorption and fatty degeneration of the cancellous tissue have occurred, fracture does take place, as a result usually of falls upon the shoulder. It is often accompanied by impaction, the head being driven into the broad surface of cancellated tissue on the upper end of the lower fragment (Fig. 285). This results in a lessening of the bulk of the upper end, or subacromial portion, of the humerus, and thus in a little flattening of the deltoid and a little increased prominence of the acromion. If impaction does not occur, and the capsule of the joint is completely torn through its entire circumference, necrosis of the upper fragment must follow. Usually, through untorn periosteum and through portions of capsule reflected from the inner side of the shaft below the anatomical neck to the edge of the articular cartilage on the head, the blood-supply is maintained so that necrosis is prevented and union results. There is no direct blood-supply to the head of the humerus corresponding to that received by the femoral head through the ligamentum teres. The displacement

is apt to be slight, the muscles inserted into the bicipital groove and acting on the lower fragment being antagonized by those inserted into the greater tuberosity. That tuberosity may be torn off as a rare accident. The displacement—theoretically—will depend upon the action of the muscles inserted into that portion of the bone (page 590).

The large upper epiphysis of the humerus (made up of centres for the head and the tuberosities which begin to coalesce about the sixth year) is fully formed by the age of puberty. It includes then the two tuberosities, the upper fourth of the bicipital groove, all of the head, the anatomical neck, and a little of the shaft just below it. A line nearly horizontal and crossing the bone beneath the great tuberosity, and therefore considerably below the anatomical neck, represents the epiphyseal line at the twentieth year, when the epiphysis and shaft become united. It is within a half inch of the so-called surgical neck (Fig. 286).

The lower surface of the epiphysis is concave and the upper surface of the diaphysis convex or conical (Fig. 287).

Fig. 286.



Upper end of humerus, showing epiphyseal line. *A*, on surface; *B*, in section.

Fig. 287.

Upper end of humerus, showing cupping of epiphysis to receive the pointed end of diaphysis.

The traumatic separation of this epiphysis is a not infrequent accident of childhood and adolescence. It is commonly caused by forcible traction of the arm upward and outward. In such cases three anatomical factors probably enter into the production of the lesion. (1) The partial fixation of the epiphysis by the subscapularis, supra- and infraspinatus, and the upper fibres of the teres minor. Even on the dead subject, rotation outward with abduction will most readily produce the disjunction. (2) The ease with which the periosteum, strongly attached to the epiphysis but very loosely to the diaphysis, may be separated from the latter. This is illustrated by the fact that in cases of detachment the teres minor, though inserted below the epiphyseal line, is apt to retain its connection with the periosteum covering the epiphysis. (3) The powerful muscles resisting abduction and inserted into the diaphysis just below the epiphyseal line.

There may be only separation with little or no displacement; but if displacement occurs, the muscles just alluded to (the latissimus, pectoral, and teres) tend to

draw the diaphyseal fragment strongly towards the chest-wall, so that its upper end may be found beneath the coracoid process. The shape of the opposing surfaces of the epiphysis and diaphysis lessens both the frequency and the amount of the displacement. The two surfaces usually remain in contact at some point: (1) on account of that shape; (2) because the humerus on the epiphyseal line is broader than at any other part of its upper end.

The deformity will be recurred to in connection with that of the conditions which it most closely resembles,—fracture of the surgical neck and dislocation of the humerus,—which (on account of the importance of muscular action in their production and in their treatment) will be considered after the muscles have been described.

It might be expected that, as the chief growth of the humerus takes place from its upper epiphysis, arrest of growth and development should be a usual sequel. The upper epiphysis from the tenth year to adult life will, according to Vogt, add from seven to ten centimetres to the length of the humerus, the lower epiphysis during the same time adding but one-fifth as much. The activity of the upper epiphysis is shown by the frequency of conical stump after amputation through the upper end of the humerus.[1] Despite these facts, in comparatively few cases of disjunction is atrophy or arrest of growth reported as a result. It has been supposed, too, that necrosis of the epiphysis should follow this injury on account of deficient blood-supply to the head; but, through the tuberosities, through the connection of the reflected capsule to the articular cartilage, and through portions of untorn periosteum, the blood-supply is ample. Firm bony union is therefore the usual result in well-treated cases. This is favored by the fact, already alluded to, that the opposing surfaces are nearly always in contact at some point.

The portion of the shaft just beneath the head and tuberosities is known as the "surgical neck" because it is so often the seat of fracture.

It contains, as will be seen on examining a longitudinal section of the humerus (Fig. 283), a considerable quantity of cancellous tissue, the absorption of which in old persons leaves the bone weak at that point. The factors already described as favoring epiphyseal separation are operative in this case (page 271).

The upper curve of the bone, beginning on this level, ends inferiorly at about the lower margin of the deltoid tubercle. Its convexity is forward and outward. The lower curve is concave forward. Both curves may be markedly increased in rickets. The middle of the bone is not only the point of union of these curves, but is also the smallest and hardest and least elastic portion of the shaft; hence it is most frequently broken, though fractures of the shaft at various levels below and above this point are not uncommon. The deltoid tubercle, when unusually developed, should not be taken for an exostosis. The region is, however, a frequent seat of bony outgrowths on account of the insertion and origin, respectively, of the coraco-brachialis and deltoid, and the brachialis anticus and internal head of the triceps.

The close attachment of the periosteum to the shaft which is thus necessitated favors the development of osteo-periostitis, and thus of osteophytes as a consequence of repeated muscular strains. Other favorite seats of exostoses are near the insertion of the pectoralis major, the latissimus dorsi, and the third head of the triceps.

Tumors of a more serious variety, especially the sarcomata, attack the humerus. The central sarcomata are found in the upper extremity chiefly at the upper end of the humerus and at the lower ends of the radius and ulna. It may be interesting to note that those are the extremities towards which the respective nutrient arteries are not directed, and therefore, in accordance with the general rule, the extremities at which bony union of the epiphyses and diaphyses takes place latest.

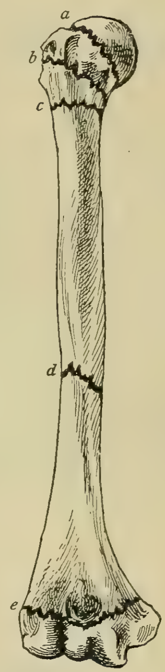
The close attachment of the periosteum at the middle of the shaft has been said to account for the fact that non-union after fracture occurs in this region more frequently than in the shaft of any other long bone of the skeleton. This has also been attributed to interference with the nutrient artery (which enters the bone near its

[1] Owen, Lejars, and others, quoted by Poland.

middle) and to imperfect immobilization of the humerus, the elbow being fixed by splints, any motion of the hand or forearm under those circumstances being transformed into motion of the upper end of the lower fragment. These may be factors, but the chief reason for non-union is the entanglement of muscular and tendinous fibres of the brachialis anticus and of the triceps between the bony fragments (page 590).

Descending the shaft it is not difficult to see why a fracture just above the condyles ("at the base of the condyles," "supracondylar") should often be met with. The olecranon fossa, the coronoid fossa, the shallower fossa for the radius just above the external condyle, all contribute to weaken the bone at this point. Moreover, in falls upon the elbow (the common cause of this fracture) the tip of the olecranon is frequently driven directly into its fossa and against the very thin lamina at its base, starting a fracture which extends laterally through the supracondylar and supratrochlear ridges to the border of the bone. If this transverse line of fracture is associated with one running perpendicularly into the joint, it constitutes the so-called "T-fracture" ("intercondylar"); it is produced in the same manner, but usually by a greater degree of force.

FIG. 288.



Lines of fractures of the humerus. *a*, through anatomical neck; *b*, through tuberosities; *c*, through surgical neck; *d*, through shaft; *e*, T-fracture involving condyles.

In the so-called "extension" and "flexion" fractures in this region the same mechanism is probably present, though it is easy to imagine the same result (if the capsule and ligaments of the elbow-joint remain intact) without the agency of the olecranon.

It should be noted that the external supracondylar ridge, the strongest and most prominent, springs from the external condyle, ascends in the line of the shaft, and terminates in the head, so that it is well adapted to receive and distribute force applied through the radius, as in falls on the hand, or in pushing or striking strongly. The external is smaller than the internal condyle because the extensors and supinators arising from it are less powerful muscles than the flexors and pronators connected with the former. This makes it less prominent; but in spite of these protective conditions it is at least as frequently broken, especially from indirect violence, because of its direct connection with the hand through the radius and capitellum. On account of the dense triceps fascia covering it, and its connection with the ligaments of the elbow-joint, the displacement is slight. The line of fracture usually passes through the radial fossa and enters the joint through the depression between the capitellum and the trochlear ridge.

The internal condyle is more often broken by direct violence, or by the wedge-like action of the olecranon starting a fracture which runs through the thin bone of the olecranon and coronoid fossæ, and through the trochlear depression. The displacement is usually upward, is the result of the force causing the break, and is but little influenced by anatomical factors. The brachialis anticus may elevate the fragment, but the ulna remains attached and prevents much displacement.

Either epicondyle may be broken. The line of the lower epiphysis runs obliquely across the bone from just above the external epicondyle to a point just below the internal epicondyle. In infancy both epicondyles (as well as the trochlea and capitellum) enter into the epiphysis; but at the thirteenth year the internal epicondyle is quite distinct, and the trochlea, capitellum, and external epicondyle are welded into the lower epiphysis proper, which by the fourteenth to the fifteenth year (Dwight), sixteenth year (Treves and Stimson), seventeenth year (Poland), is firmly united to the diaphysis. After the thirteenth year, therefore, separation of the epiphysis will probably leave the internal epicondyle attached to the diaphysis. "The point of junction of the trochlear and capitellar portions of the lower epiphysis at the middle of the trochlear groove at the sixteenth year

is the narrowest portion of the bone, and much more likely to be broken across, detaching one or other portion of bone rather than the whole epiphysis separating at this age" (Poland).

As the synovial membrane is attached on the inner side about five millimetres (three-sixteenths of an inch) below the internal epicondyle, fracture of the latter does not necessarily extend into the joint-cavity. On the outer side it is attached up to the level of the external epicondyle, so that the joint is likely to be involved in traumatic separation of that process.

As the capsule of the joint is attached at a higher level than the epiphysis in front, behind, and laterally, the displacement in epiphyseal separations is within the capsule, and therefore likely to be limited. The close relationship of the synovial membrane gives rise, however, to extensive effusion, which affects both diagnosis and treatment.

The union to the diaphysis at about the fifteenth year leaves the further growth of the bone dependent upon the upper epiphysis (page 272); hence injuries involving the epiphysis, or excision of the elbow in which the epiphyseal limits are overstepped, will not be followed by arrest of growth if the patient is more than fifteen years of age.

Epiphysitis, on account of the synovial and capsular relations above described, is apt to involve the elbow-joint, and to result in considerable stiffness.

The anatomical deformity and diagnosis of epiphyseal separation will be considered in connection with the subjects of supracondylar fracture and luxation of the elbow (page 590).

About two inches above the inner condyle there is often found (one per cent. of recent skeletons, Turner) a hook-like process projecting downward and converted into a foramen by a ligamentous band. When it is present the median nerve usually passes through it, which demonstrates that "it is the homologue and rudiment of the supracondyloid foramen of the lower animals" (Darwin). The process can sometimes be recognized by the sense of touch. The intercondylar foramen, which is occasionally present in man, occurs, but not constantly, in various anthropoid apes, and, though it weakens the bone somewhat, is chiefly interesting because it is found in much greater frequency in skeletons of ancient times, and thus illustrates Darwin's assertion that "ancient races more frequently present structures which resemble those of the lower animals than do modern."

THE SHOULDER-JOINT.

The ligaments of this articulation are :

Capsular; Glenoid

Accessory ligaments :

Coraco-Humeral ; Gleno-Humeral.

This is a very simple instance of the ball-and-socket joint, the only irregularity being the position of the humeral head somewhat on one side instead of at the top of the bone, so that the axis of rotation does not correspond with the axis of the shaft.

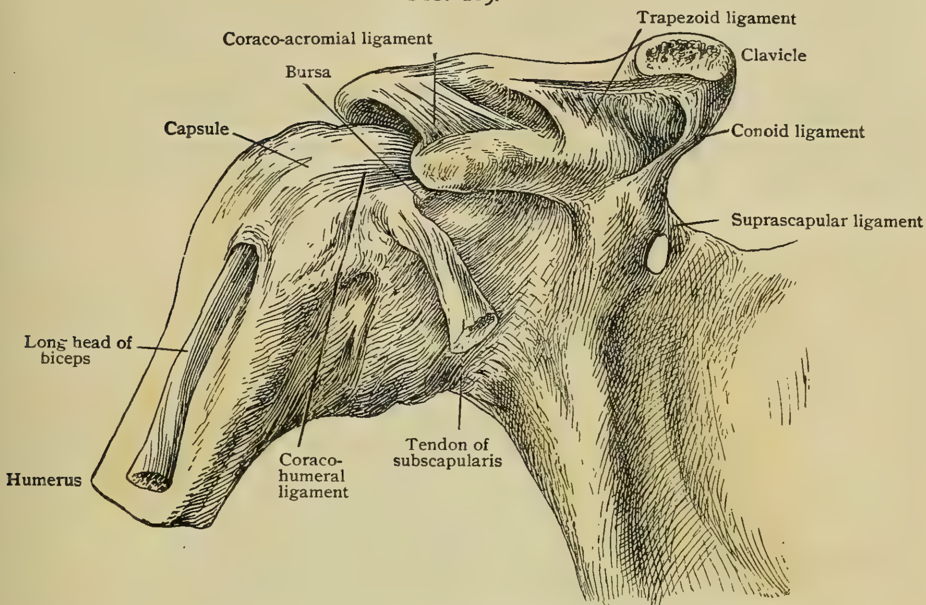
The shallow socket of the glenoid cavity, lined with articular cartilage, is deepened by the **glenoid ligament**[1] (Figs. 290, 292), a fibro-cartilaginous band attached by its base to the border of the cavity and ending in a sharp edge. It is thus triangular on section (Fig. 291), the breadth of the base being five millimetres and the height at its greatest about one centimetre. This ligament is composed chiefly of fibres running around the socket. It is directly continuous with the fibres of the long head of the biceps from the insertion of the latter into the top of the socket.

The **capsular ligament**[2] (Fig. 289) is so lax that in the dissected joint the head of the humerus falls away from the socket. In life it is kept in place chiefly by the tonicity of the surrounding muscles. The course of the fibres is in the main longitudinal, but they are indistinct. The capsule arises above from the edge of the

[1] Labrum glenoidale. [2] Capsula articularis.

glenoid cavity and the bone just around it, from the outer surface of the glenoid ligament as far as its edge, excepting at the top, where it does not encroach on the ligament, and at the inner side, where its origin is uncertain. It may arise there as

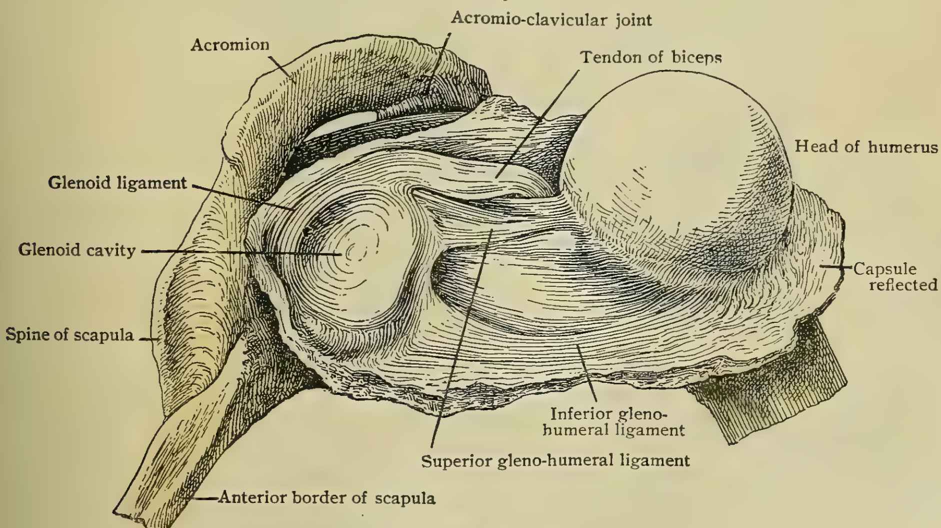
FIG. 289.



Right shoulder-joint from before.

described, but very often it arises at some distance from the border of the joint from the anterior surface of the scapula. In exceptional cases this distance may be half an inch, perhaps more. The inferior attachment of the capsular ligament is to the

FIG. 290.



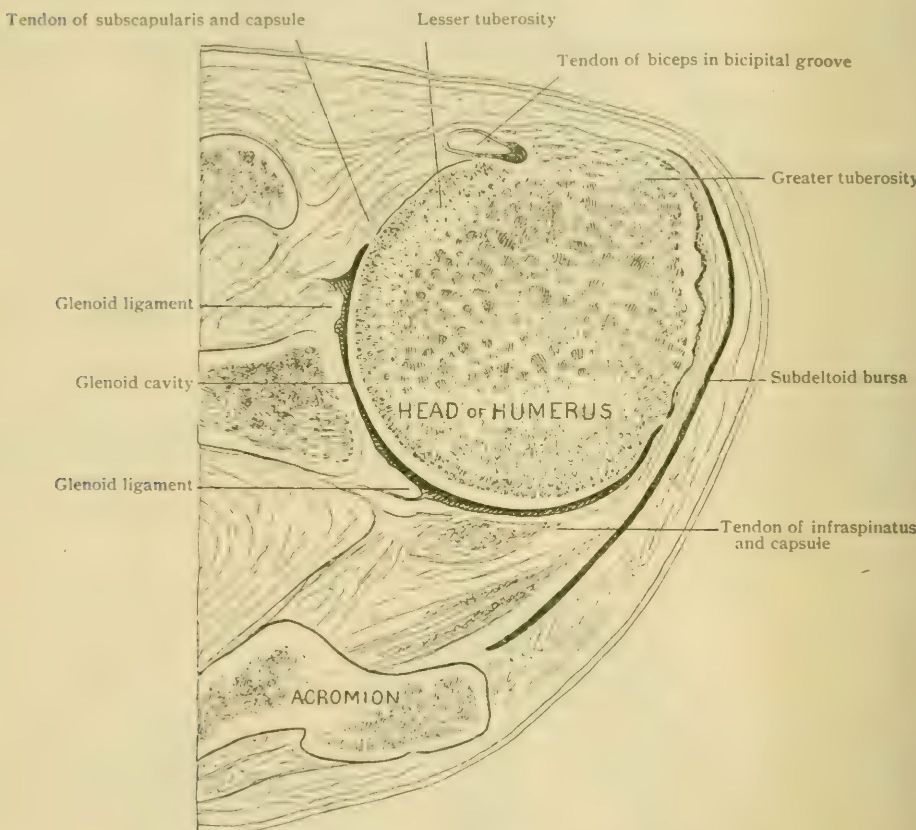
Right shoulder-joint, capsule opened and humerus everted.

groove round the head, close to the latter above and externally, but a little way from it below and internally. This applies to the attachment as seen from within

the opened joint; on the outside, the fibres can be traced for a considerable distance from the joint before they are lost in the periosteum. Fibres going to the tuberosities blend with the tendons of insertion of the muscles of the scapular group, the supra- and infraspinati, the teres minor, and the subscapularis, which materially strengthen the capsule. The latter is thinnest behind.

Certain **accessory ligaments** strengthen the capsule. The most important is the *coraco-humeral* (Fig. 289), which, arising from the outer edge of the horizontal portion of the coracoid where a bursa separates it from the capsule, soon fuses with the latter and runs, without very distinct borders, to both tuberosities, crossing the bicipital groove. A few transverse fibres (the *transverse humeral ligament*) bridge in the bicipital groove below the capsule proper. Three *gleno-humeral bands* (Fig. 290) are described on the inside of the capsule, of which the most important is the

FIG. 291.



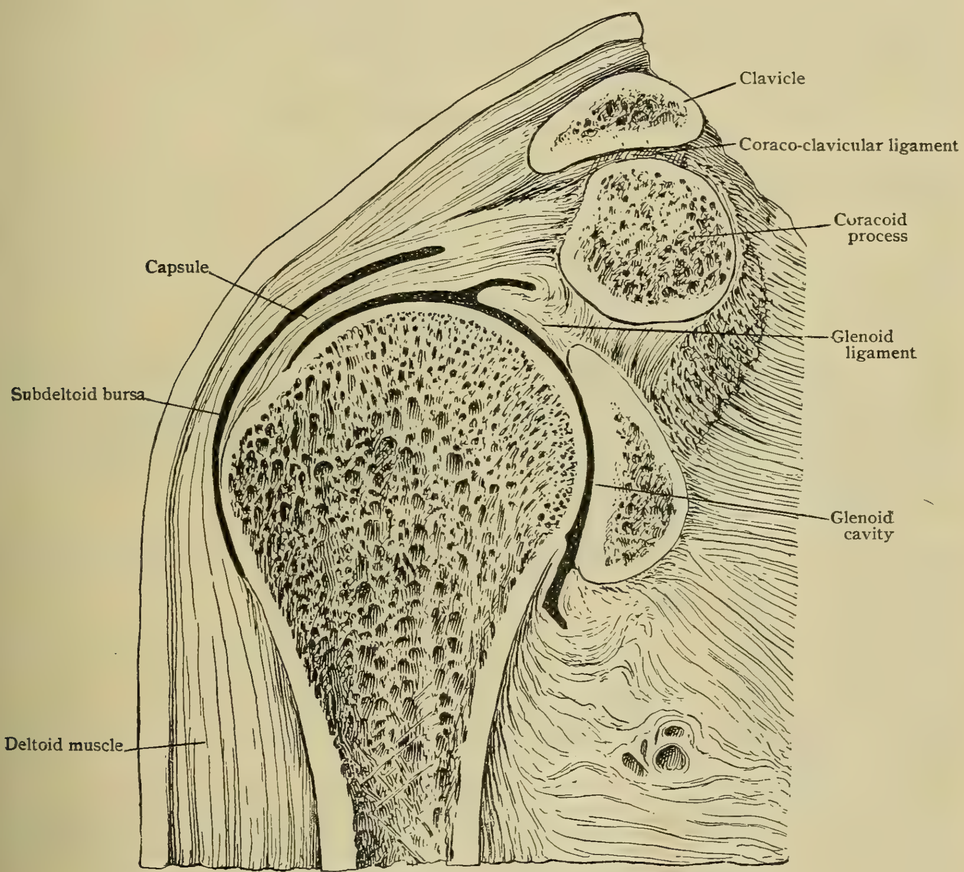
Horizontal frozen section through the right shoulder-joint from above.

superior. This band springs from near the top of the inner border of the glenoid cavity and is inserted into the lesser tuberosity. In a part of its course it makes a prominent fold of the synovial membrane along the inner border of the tendon of the long head of the biceps. This ligament has been described as a deep part of the coraco-humeral. The *middle ligament* is ill-defined. The *inferior*, running from the lower end of the glenoid socket to the inner side of the neck of the humerus, may be seen both from without and within the capsule. It is made tense when the arm is abducted, and materially strengthens the joint. The capsule usually presents an opening on the inner side in the upper part, by which the bursa below the tendon of the subscapularis communicates with the joint. The cases in which the capsule

arises internally at quite a distance from the glenoid cavity are probably due to a very free opening into a large bursa. The tendon of the long head of the biceps lies within the capsule from its origin at the top of the glenoid till it leaves the capsule in the bicipital groove. The tendon does not lie free within the joint, but is covered by a reflection of the synovial membrane as it lies curved over the head of the humerus. On the young fœtus it is attached to the inside of the capsule by a synovial fold. The *synovial membrane* of this joint is remarkably free from synovial fringes.

The **bursæ** about the joint are numerous. The largest is the *subacromial* or *subdeltoid bursa* (Figs. 291, 292), situated between the top of the capsule, the coraco-acromial ligament, and the acromion, and extending downward under the deltoid. The *subcoracoid bursa* separates that process and the beginning of the

FIG. 292.



Frontal frozen section through the right shoulder-joint.

coraco-humeral ligament from the capsule. Other bursæ are often found between the capsule and the muscles inserted into the tuberosities ; that under the *subscapularis* is constant. Of the others, the one most frequently found is under the infraspinatus ; it also may open into the joint.

Movements.—When the arm is hanging close to the side *adduction* is almost wanting, since, apart from the interference of the body, the humerus is arrested at once by the lower border of the glenoid cavity. *Backward movement* is not free, for the arm soon impinges on the overhanging acromion. *Abduction* has a range of some 90° before the tenseness of the lower part of the capsule stops it.

(Unless the arm is raised somewhat forward, it is stopped still sooner by the acromion.) *Forward movement* is about equal to abduction, and is checked in the same way. When the arm is at a right angle with the body, the range of motion in a horizontal plane is about 90°. The degree of *rotation* in the shoulder is very variable. It is greatest when the arm is partially abducted, when in a dissected joint it may approximate 135°. When raised to a right angle it is about 90°, and in the hanging arm, if not closely adducted, nearly the same. *Circumduction* is free.

Probably none of the important joints is so dependent on others as that of the shoulder. The scapula takes part in practically all the movements, not waiting till the range of movement at the shoulder is exhausted, but sharing in it from the start. The acromion and coraco-acromial ligament make an extra socket under certain circumstances, as when the body is supported by the arms, the subacromial bursa acting as a synovial membrane. The long head of the biceps is a great assistance to the stability of the joint, the muscle pulling the bones firmly together and making them rigid under circumstances of strain. It has the further advantage over a ligament that its tension can vary without change of position.

PRACTICAL CONSIDERATIONS.

The extremely wide range of motion of the humerus upon the scapula in the human species is associated, for mechanical reasons, with many anatomical conditions of interest to the surgeon. The most important of these conditions in relation to displacement are: (1) The shallowness of the glenoid cavity. (2) The relatively large size of the humeral head, only one-third of which is in contact with the glenoid surface when the arm is by the side of the body. (3) The thinness and the great laxity of the capsule, which, if fully distended, would accommodate a bulk twice as large as the head of the humerus. This laxity (to permit of free elevation of the arm) is greater at the inferior portion of the joint. The primary office of the capsular ligament in this joint is not to maintain apposition, but to limit movement. (4) The maintenance of the contact between the articular surfaces by muscular action, aided by atmospheric pressure, and not by the ligamentous or capsular attachments. (5) The length of the humerus, affording a very long leverage; and the exposed position of the shoulder.

All these circumstances favor dislocation, and render this joint more frequently the subject of that accident than any other joint in the body. The usual position in which luxation occurs is that of abduction and advancement of the arm, as in falls on the hand.

It is to be noted that this attitude brings the most prominent part of the lower edge of the head of the bone against the thinnest and weakest part of the capsule. Moreover, the greatest diameter of the head of the humerus is involved, adding to the pressure against the capsule (Fig. 293). As such accidents happen suddenly, the muscles are usually taken off their guard, and hence that source of protection to the joint is lacking.

As opposed to these factors, and as tending to prevent displacement, should be mentioned: (1) The exceptional relation of the biceps tendon to the joint, strengthening the capsule at its upper portion, preventing the humerus from being too strongly pressed against the acromion by the powerful deltoid and the other elevators of the arm; steadying the head of the bone through its connection in the bicipital groove, in which way "it serves the purpose of a ligament, with the advantage of being available in all positions of the joint, and without restricting the range of movement in any direction" (Humphry). (2) The arrangement of the glenoid cup, the inner and lower edges of which are more prominent than the outer and upper, resisting somewhat the tendency of the powerful axillary muscles, and of blows on the shoulder, to displace the humerus inward, and of falls with the arm in abduction, to displace it downward. (3) The glenoid ligament deepening the articular cavity, and aided in this by the insertions of the long head of the biceps above and the scapular head of the triceps below. (4) The resistance offered by the strong coraco-acromial ligament to any upward displacement. If it were not for

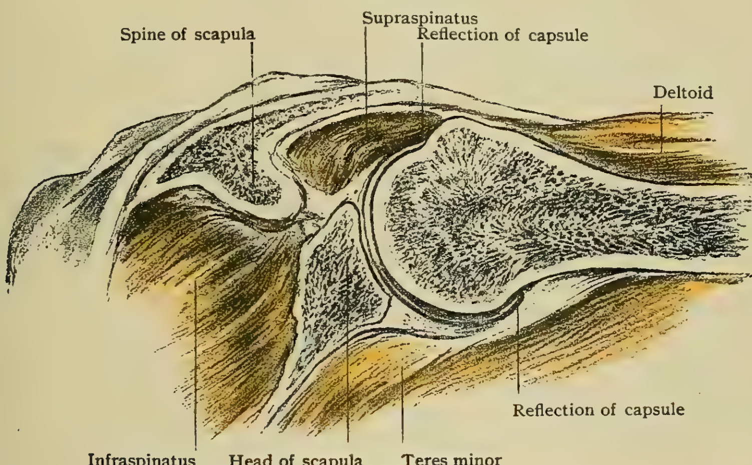
these provisions, luxations of the shoulder would be even more frequent than they are.

The head of the bone may leave the joint-cavity at other points than the inferior. If the force is so applied as to drive the head of the bone against the capsule at the anterior portion, a direct subcoracoid luxation may result; if against the posterior portion, a subspinous. The latter is very rare, and the former is also rare as a primary luxation.

The further mechanism of luxations, their deformities and anatomical diagnosis, will be considered after the muscles, which are such important factors in producing and modifying them, have been described (page 582).

Disease of the shoulder-joint may be of any variety. In spite of the frequent strains to which the joint is subjected and its wide range of movement, the diseases produced by traumatism are not exceptionally frequent. This is probably because of (1) its ample covering of muscles protecting it from the effects of cold and damp. (2) The mobility of the scapular segment of the shoulder-girdle lessening greatly the effect of traumatisms. (3) The laxity of its capsular and synovial elements, which, though it favors luxation, permits a moderate effusion to occur without harmful tension. (4) The influence of the weight of the upper extremity in the usual position of the body in resisting by gravity the destructive pressure of joint surfaces against each other, caused by muscular spasm after injury or during disease. (5) The

FIG. 293.



Section through right shoulder-joint with arm in abduction.

ease with which the joint may be immobilized without irksome confinement of the patient.

These circumstances, especially the latter, account also for the facts that tuberculous disease of the joint and epiphysitis involving the joint are not so common as in other joints, and that the results are exceptionally good, operative interference being required with comparative rarity.

Synovial distention causes a uniform rounded swelling of the shoulder, but it can best be recognized by the touch in the bicipital groove, where one synovial diverticulum runs, and in the axilla, where part of the capsule is exposed beyond the margin of the subscapular muscle. The diverticula beneath the tendons of that muscle and (more rarely) of the infraspinatus are usually involved, pain when the arm is rotated being a resultant symptom.

The subdeltoid bursa does not usually communicate with the joint. It may be the subject of independent disease. When it is inflamed the position of ease will be one which relaxes the deltoid (abduction of the arm), and rotation or pressure upward will be painless. In disease of the subacromial bursa, abduction and upward pressure are painful because the sac is then pinched between

the head of the bone and the under surface of the acromion and coraco-acromial ligament.

When suppuration occurs, pus may find its way out from the joint. (1) By following the bicipital tendon and opening on the arm below the anterior border of the axilla. (2) By following the subscapular tendon, getting between that muscle and the body of the scapula, and opening beneath and behind the axilla. (3) By penetrating the capsule beneath the deltoid, when the dense deltoid and infraspinous fascia prevent it from going backward and direct it to the anterior aspect of the arm. Treves mentions a case in which it followed the course of the musculo-spiral nerve and appeared on the outer side of the elbow.

Landmarks.—The edge of the acromion and the tip of the coracoid can readily be felt, though the coraco-acromial ligament completing the important arch above the joint is beneath the deltoid, and therefore cannot be so distinctly palpated, but can usually be recognized by touch. An incision through the centre of this ligament would open the shoulder-joint where the bicipital tendon enters its groove. The head of the bone, when pressed upward against this arch, communicates motion to the outer fragment in cases of fractured clavicle, and this is often the easiest way in that lesion of eliciting crepitus and preternatural mobility. In cases of paresis or paralysis of the deltoid, the resultant atrophy may leave the whole arch palpable, or even visible, in some instances the bone dropping from one to several inches.

The lower margin of the glenoid cup and the head of the humerus may be felt in the axilla when the arm is abducted (Fig. 293).

The greater tuberosity may be felt through the deltoid, directly beneath the acromion, the arm hanging at the side. It faces in the direction of the external condyle. Together with the lesser tuberosity it produces the normal roundness of the deltoid.

The head of the bone cannot be felt externally. It faces in the general direction of the internal condyle. Two-thirds of it, when the arm is by the side, is in front of a vertical line drawn from the anterior border of the acromion process. It is also altogether external to the coracoid process.

The lesser tuberosity faces forward. Between it and the greater tuberosity, when the arm is hanging loosely and is supine, the lower part of the bicipital groove may be felt in thin subjects. This also faces directly forward, and is on a line drawn through the middle of the biceps and its lower tendon.

The upper part of the humeral shaft cannot be felt. The circumflex nerve winds around it a little above the middle of the deltoid. The deltoid tubercle may be recognized at the middle of the arm. From there downward the bone is more superficial externally, and the outer supracondylar ridge may be traced down to the condyle. The less prominent internal ridge can be felt only for a short distance above the elbow.

The middle of the humerus, indicated by the insertion of the deltoid on the outer side, is also on a level with that of the coraco-brachialis on the inner and with the upper portion of the brachialis anticus on the anterior surface, with the origin of the nutrient and inferior profunda arteries, with the exit through the deep fascia of the nerve of Wrisberg and the entrance of the basilic vein, with the passage of the median nerve across the brachial artery, and with the departure of the ulnar nerve from its proximity to the vessel. Posteriorly, the middle of the bone is covered by the triceps.

Just below the middle the musculo-spiral nerve and the superior profunda wind around in the groove below the deltoid insertion, and the inner head of the triceps arises from the bone.

At the junction of the middle and lower thirds the brachial artery from the inner side and the musculo-spiral nerve from the outer side tend to approach the front of the bone.

The landmarks at the lower extremity will be considered in relation to the elbow-joint and the bones of the forearm.

The surface anatomy and the relations of the soft parts to the humerus will be recurred to after those structures have been described.

THE FOREARM.

The skeleton of the forearm consists of two bones,—an inner, the *ulna*, and an outer, the *radius*. The former is large above and small below ; the latter, the converse. The ulna plays around the trochlea in flexion and extension, carrying the radius with it. The radius plays on the ulna in pronation and supination, carrying with it the hand. These bones are connected by an interosseous membrane, which gives origin to muscles, adds to the security of the framework, and yet implies a great saving in weight.

THE ULNA.

The ulna consists of a shaft and two extremities.

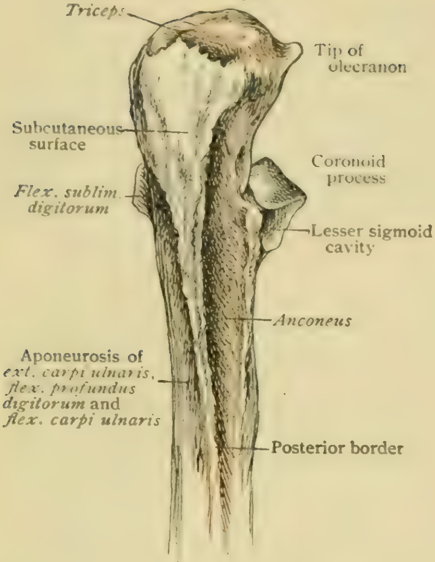
The **upper extremity** is devoted to the joint with the humerus, and laterally to that with the head of the radius. The former articular surface is the *greater sigmoid cavity* hollowed out of the continuous surfaces of the *olecranon process* behind and above and the *coronoid process* in front. The **olecranon**,[1] a cubical piece of bone projecting upward in continuation with the shaft, presents this articular surface in front (to be described later), and a superior, a posterior, and two lateral surfaces. The *superior surface* is pointed in front. with the point or *beak* external to the middle. A slight groove just back of the edge serves for the attachment of the capsular ligament. Behind this are two parts of different texture, the posterior of which is for the insertion of the triceps. The *posterior surface* is triangular, bounded above by the irregular edge of the top, and laterally by two lines which meet below to make the posterior border of the shaft. It is subcutaneous, and is covered by a bursa (Fig. 294). The *outer surface* is bounded in front by the sharp edge of the sigmoid cavity, along which is the groove for the capsule. Behind this is a hollow for the anconeus. The *inner surface* has in front the inner border of the sigmoid, less sharp than the outer, the capsular groove, and farther back a rough elevation. The **coronoid process**[2] rises from the anterior surface of the front of the shaft. It has an *upper*, articular surface, an *anterior*, and two *lateral* ones. The front surface rises to a point nearer the outer side. The capsular groove runs along the border ; and below this, bounded by two lines meeting below, is a rough region for the brachialis anticus. Within the angle formed by the meeting of these two lines is a rough rounded space, the *tuberosity* of the ulna, from the edge of which arises the oblique ligament. The brachialis anticus is inserted into the lower part of this surface and the tuberosity. The *inner surface* is bounded above by the sharp projecting border of the sigmoid cavity, at the edge of which is a rough prominence from which certain fibres of the flexor sublimis digitorum take origin. The outer surface presents the *lesser sigmoid cavity*.

The **greater sigmoid cavity**[3] occupies the anterior surface of the olecranon and the superior one of the coronoid process. There is a constriction in the middle of both borders, but deeper in the outer, where the two processes meet, and the articular surface on the dry bone seems often to be interrupted in a line between them. The sigmoid cavity, concave from above downward, is broader in the upper half than the lower. It is surrounded, except where it is joined by the lesser sigmoid cavity, by an ill-marked groove for the capsular ligament. The articular surface is subdivided by a rounded ridge, running from the point of the olecranon to that of the coronoid, into a larger inner and a smaller outer portion. The course of this ridge is generally somewhat inward as well as downward. This and the cross-line divide the articular surface into four spaces. Of the upper, the inner is concave and the outer convex from side to side. Of the lower, the inner is concave in the same direction and the curve of the outer is uncertain ; probably, as a rule, slightly concave, it may be plane or a little convex.

The **lesser sigmoid cavity**,[4] for the head of the radius, is a concavity on the outer side of the coronoid process, separated from the greater by a ridge, which does not interrupt the cartilage coating both. It generally is an oblong quadrilateral area forming about one-sixth of the circumference of a cylinder, with parallel borders ;

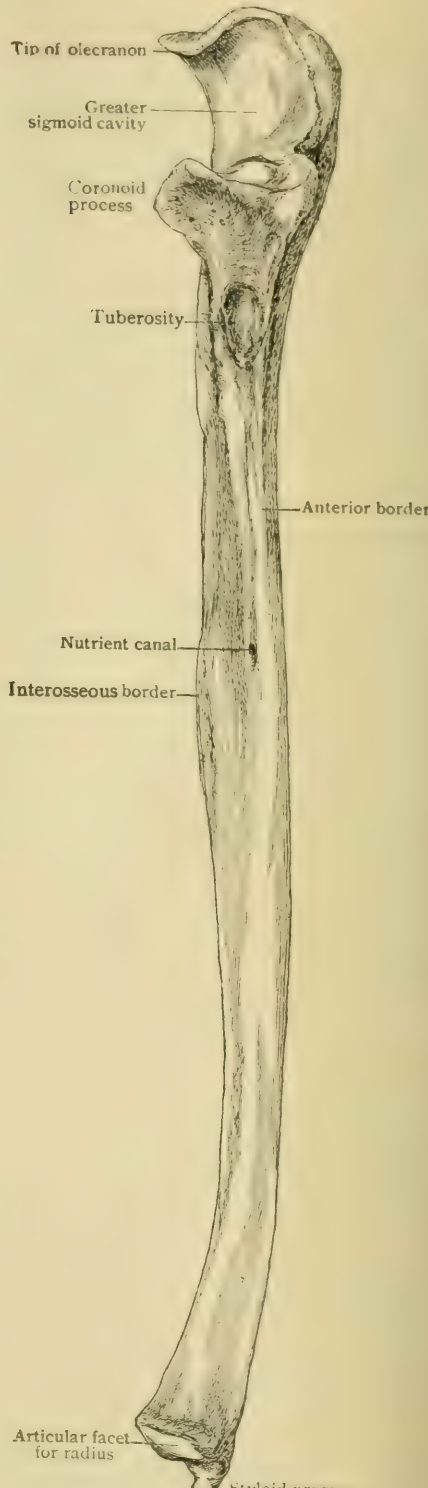
[1] Olecranon. [2] Processus coronoideus. [3] Incisura semilunaris. [4] Incisura radialis.

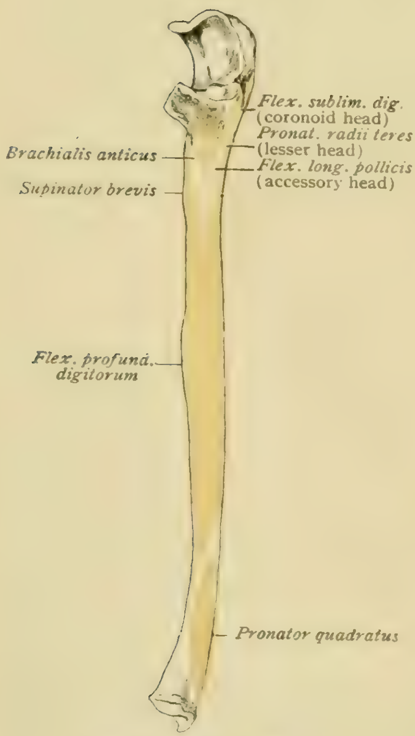
FIG. 294.



Upper end of right ulna, posterior aspect.

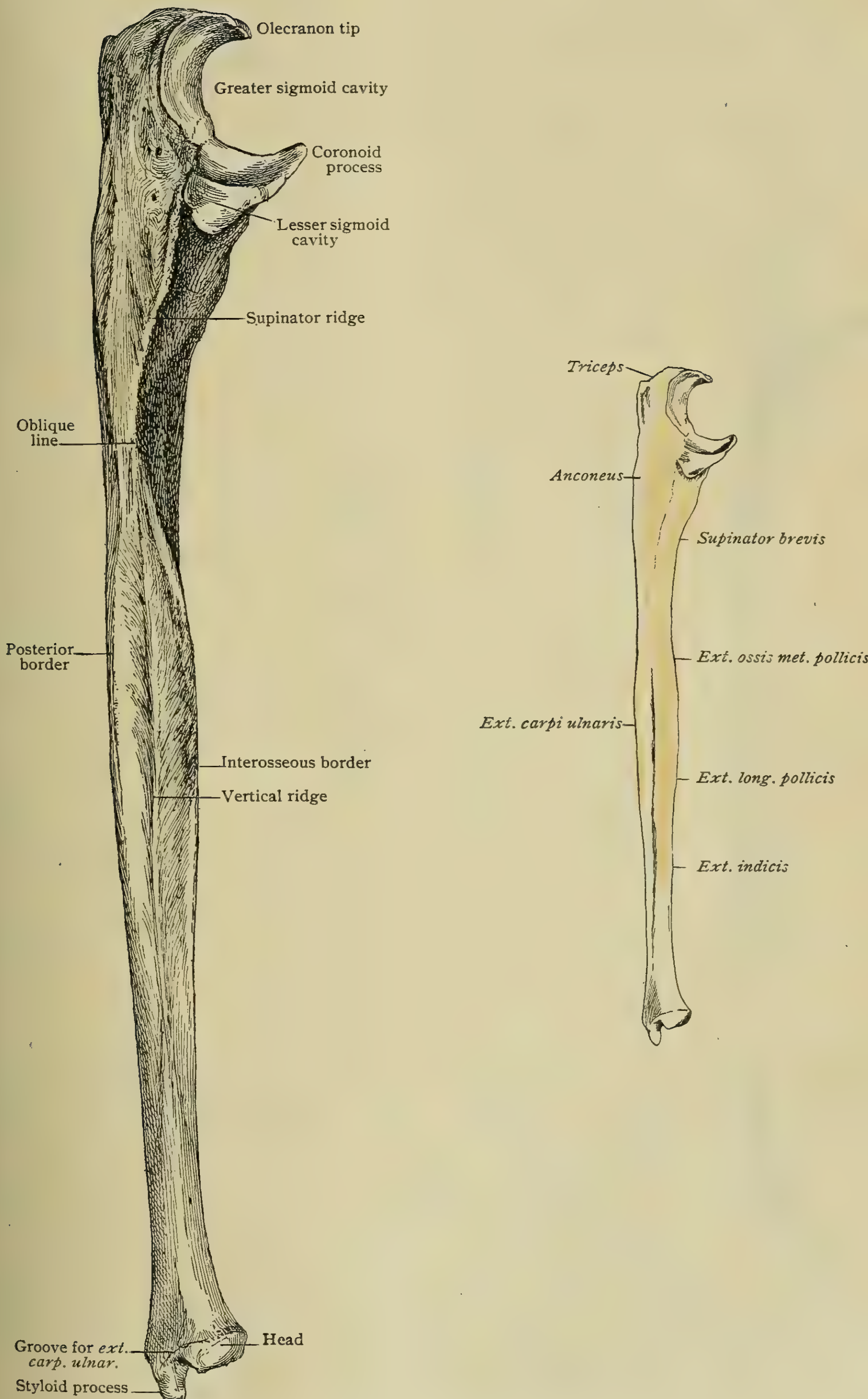
FIG. 295.





Right ulna, inner aspect. The outline figure shows the areas of muscular attachment

FIG. 296.

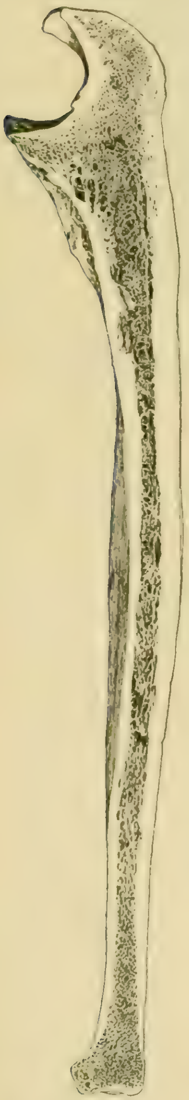


Right ulna, outer aspect. The outline figure shows the areas of muscular attachment.

but sometimes the front border is short and the inferior runs obliquely backward, making it almost triangular.

The **shaft**,[1] which presents three borders and three surfaces, steadily diminishes from above downward. In the upper part the bone curves slightly backward and outward (*i.e.*, towards the radius), then inward through the greater part of its extent, till at the lower quarter it again bends outward and, at the same time, forward. The *posterior border*[2] is formed by the union of the two lines bounding the subcutaneous surface at the back of the olecranon. Following the curves just described, it runs to the back of the styloid process, being very distinct in the first two-thirds, where it gives origin to the aponeurosis of the flexor carpi ulnaris. The *anterior border*,[3] springing from the junction of the front and inner sides of the coronoid, runs down to end just above the front of the styloid process. Its last quarter, which is rough to give origin to the pronator quadratus, has a backward slant. The *outer* or *interosseous border*[4] is very sharp in the middle two-fourths of the shaft, where it gives origin to that membrane. It begins above by the union of two lines, which, starting from the front and back of the lesser sigmoid cavity, bound a triangular depression. The posterior of these lines, sharp and raised, is the *supinator ridge*. The depression which gives origin to the supinator brevis receives the bicipital tuberosity of the radius in pronation. The border becomes indistinct below and is lost as it approaches the head of the ulna. The *anterior surface* is usually concave throughout, though the upper part may be convex. In the third quarter a line often appears which slants downward into the front border, giving origin to the upper fibres of the pronator quadratus. Below this line, when present, there is a depression occupied by that muscle. Above this arises the flexor profundus digitorum. The nutrient foramen running upward is a little above the middle. The *inner surface*, concave at the side of the upper extremity and convex below, gives further origin in its upper two-thirds to the last-named muscle. The *posterior surface* has several features which are to be recognized only on a well-marked bone, and are very variable. The *oblique line* starts from the supinator ridge, or from the hind edge of the lesser sigmoid cavity, and runs downward to the posterior border at the end of the first third. It gives origin to a part of the supinator brevis, and helps to mark off a three-sided depression running onto the olecranon for the anconeus. It is sometimes the apparent continuation of the supinator ridge, as in Fig. 296. The region below this is subdivided by a *vertical ridge* of uncertain beginning and end. Sometimes it springs from the interosseous border, and it is usually lost below in the hind one. The extensor carpi ulnaris springs from the surface internal to it, which is sometimes a deep gutter. External to the vertical ridge are areas for the extensor ossis metacarpi pollicis, extensor longus pollicis, and extensor indicis from above downward in the order named.

FIG. 297.



Longitudinal section of ulna.

The **lower extremity** of the ulna consists of the head and the styloid process. The **head**[5] is a rounded enlargement projecting forward and outward, presenting an articular surface on the outer side, which passes onto the front and the back, making at least two-thirds of a circle, around which the radius swings. A ridge marks the upper border of this surface, which overhangs the lower. The latter is rounded, so that the lateral articular surface continues without real interruption into the inferior, which is separated from the wrist-joint by the triangular fibro-cartilage. The under side of the articular surface is somewhat kidney-shaped, the concavity looking towards the styloid process, from which it is separated by a groove for the

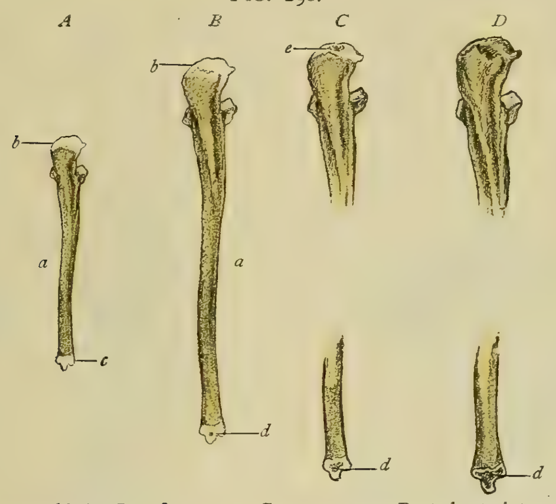
[1] Corpus ulnae. [2] Margo dorsalis. [3] Margo volaris. [4] Crista interossea. [5] Capitulum.

attachment of the fibro-cartilage. The **styloid process** is a short, slender process running down from what may be called the posterior internal angle of the lower end. There is a distinct groove between the styloid process and the head on the posterior aspect, and sometimes a faint one in front, transmitting respectively the tendons of the extensor and the flexor carpi ulnaris.

Structure.—There is much solid bone in the shaft, and altogether the ulna is a strong-walled bone. Many plates near together from the anterior surface pass upward under the coronoid process to the middle of the greater sigmoid notch. The best-marked system of plates in the coronoid is in the main parallel to these. The greater sigmoid notch is bounded by compact substance. Sagittal sections show plates radiating from it, some of which form arches near the top of the olecranon with others from the posterior surface. The head is composed of spongy tissue within thin walls.

Development.—The centre for the shaft appears in the eighth week, from which practically all the bone except the lower end is developed. At about five,

FIG. 298.



Ossification of ulna. *A*, at birth; *B*, at five years; *C*, at ten years; *D*, at about sixteen years. *a*, centre for shaft; *b*, *c*, cartilaginous epiphyses; *d*, centre for lower epiphysis; *e*, for upper epiphysis.

one appears for the head and styloid process; and at about ten, one for the top of the olecranon. This fuses at about sixteen; the lower end joins the shaft at eighteen.

PRACTICAL CONSIDERATIONS.

The ulna may be absent, or may be more or less defective in size or shape. Such deformities are not common. Fracture of the olecranon at its junction with the shaft, where it is narrowed, is frequent. The degree of displacement is largely determined, as in the parallel case of the patella, by the amount of laceration of the enveloping fibrous structure (Fig. 585). If this is great, the triceps strongly elevates the fractured process. Occasionally the mere tip of the olecranon, or even a thin portion of the superficies only, may be separated either by muscular action or by direct violence.

The epiphyseal line is above the constriction that marks the union of the olecranon with the shaft. The epiphysis is small and includes the upper part of the olecranon with the insertion of the triceps, a part only of the attachment of the posterior ligament, and a very small portion of the posterior triangular subcutaneous surface. The epiphyseal line runs from the upper part of the sigmoid cavity in front downward and backward. The epiphysis enters but little into the elbow-joint; it is largely within the limits of strong periosteal and tendinous and ligamentous expansions, is of small size, and before the fourteenth or fifteenth year is on a

plane anterior to the epicondyles. For these anatomical reasons, neither muscular action (triceps) nor falls on the elbow are so productive of separation of this epiphysis in children as of fracture of the olecranon in adults. It is, in fact, one of the rarest of epiphyseal disjunctions. The symptoms are very similar to those of fractured olecranon.

FIG. 299.

Lines of fracture of coronoid, olecranon, and styloid processes of ulna.

The coronoid process is rarely broken except in cases of dislocation of the forearm backward from falls upon the hand. The mechanism is obvious. The force is applied through the medium of the oblique fibres of the interosseous membrane. The line of fracture is nearer the tip than the base of the process. The insertion of the brachialis anticus tendon in the latter region prevents much displacement of the fragment, and the attachment of the capsule of the joint to its edge insures a sufficient vascular supply for purposes of repair. Great proneness to recurrence after reduction in a case of backward dislocation of the forearm should lead to a suspicion of the existence of this fracture.

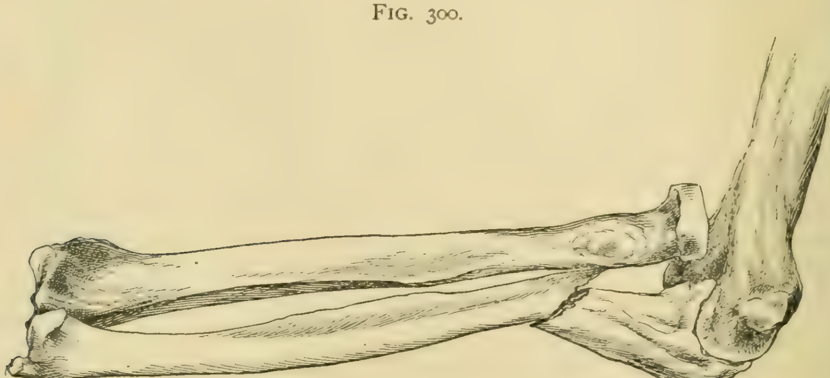
Fracture of the shaft of the ulna alone may occur at any point, and is usually the result of direct violence, as when the arm is raised to protect the head from a blow, or in a fall upon the ulnar side of the forearm. In the latter case, when the ulnar fracture is in the upper third, it is not infrequently associated with forward dislocation of the head of the radius (Fig. 300).

The subcutaneous position of the ulna renders fracture frequently compound. This accounts for the greater frequency of non-union in this bone as compared with the radius. In fracture at the lower third the lower fragment is drawn towards the radius by the pronator quadratus.

Fractures associated with those of the radial shaft will be considered in relation to the effect of muscular action upon them (page 604).

The lower epiphysis of the ulna comprises the articular surfaces on the radial and inferior aspects and the styloid process. It is concave superiorly to fit the rounded lower end of the diaphysis. The level of the epiphyseal line is about one-sixteenth of an inch above the level of that of the radius. This epiphysis is strongly

FIG. 300.



Fracture of upper third of ulna, with dislocation of radius forward.

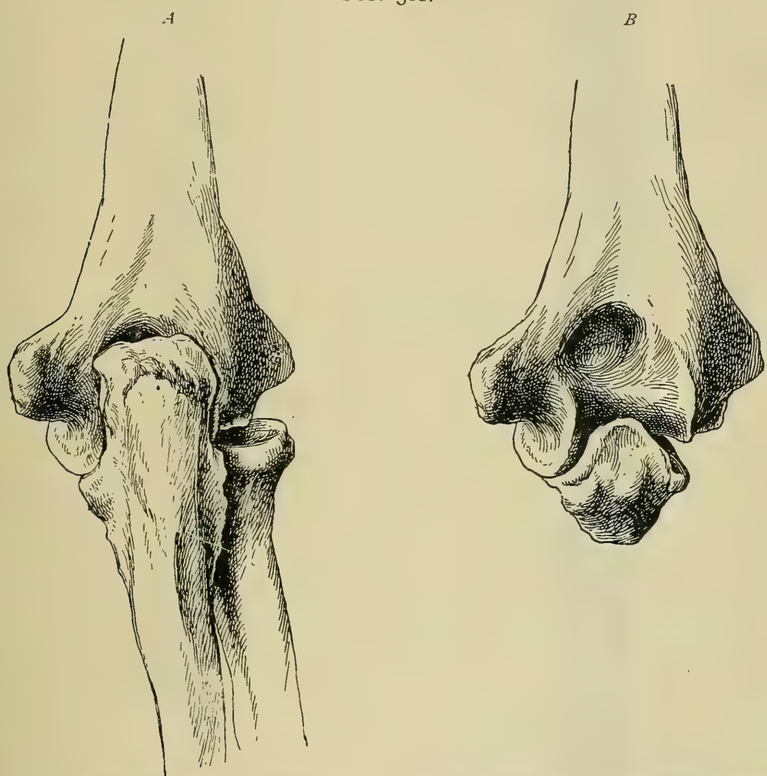
held to the lower epiphysis of the radius by the inferior radio-ulnar ligaments and also by the triangular fibro-cartilage extending from the root of the styloid process to the concave margin of the radius. For that reason, and because of its indirect relation to the hand, the uncomplicated separation of this epiphysis is of great

rarity. Even in cases of separation of the lower epiphysis of the radius, or of Colles's fracture, the strain reaches the tip of the ulnar styloid through the internal lateral ligament and produces fracture of that process, or of the ulnar diaphysis at its smallest point (about three-quarters of an inch above the lower end), rather than separation of the epiphysis.

As the growth of the ulna depends almost exclusively upon the lower epiphysis, injuries stopping short of recognizable disjunction have been followed in a number of cases by failure of development, resulting in lateral displacement (adduction) of the hand.

Landmarks.—The olecranon can always easily be felt at the back of the elbow. It is somewhat nearer the internal than the external condyle. With the forearm at right angles to the arm, the tip of the olecranon and the two condyles

FIG. 301.



Posterior view of elbow, showing relative position of condyles and olecranon. *A*, in extension; *B*, in flexion.

are on the same plane as the back of the upper arm. In extreme extension it is about one-sixteenth of an inch or less above a straight transverse line joining the two condyles; in full flexion it is anterior to them. In front the tip of the coronoid process can be felt with difficulty in non-muscular subjects. The shaft is subcutaneous through its entire length. The styloid process is a half-inch nearer the forearm than the styloid process of the radius. It is most distinct in full supination, and is found at the inner and posterior aspect of the wrist. In full pronation the head of the ulna becomes prominent posteriorly.

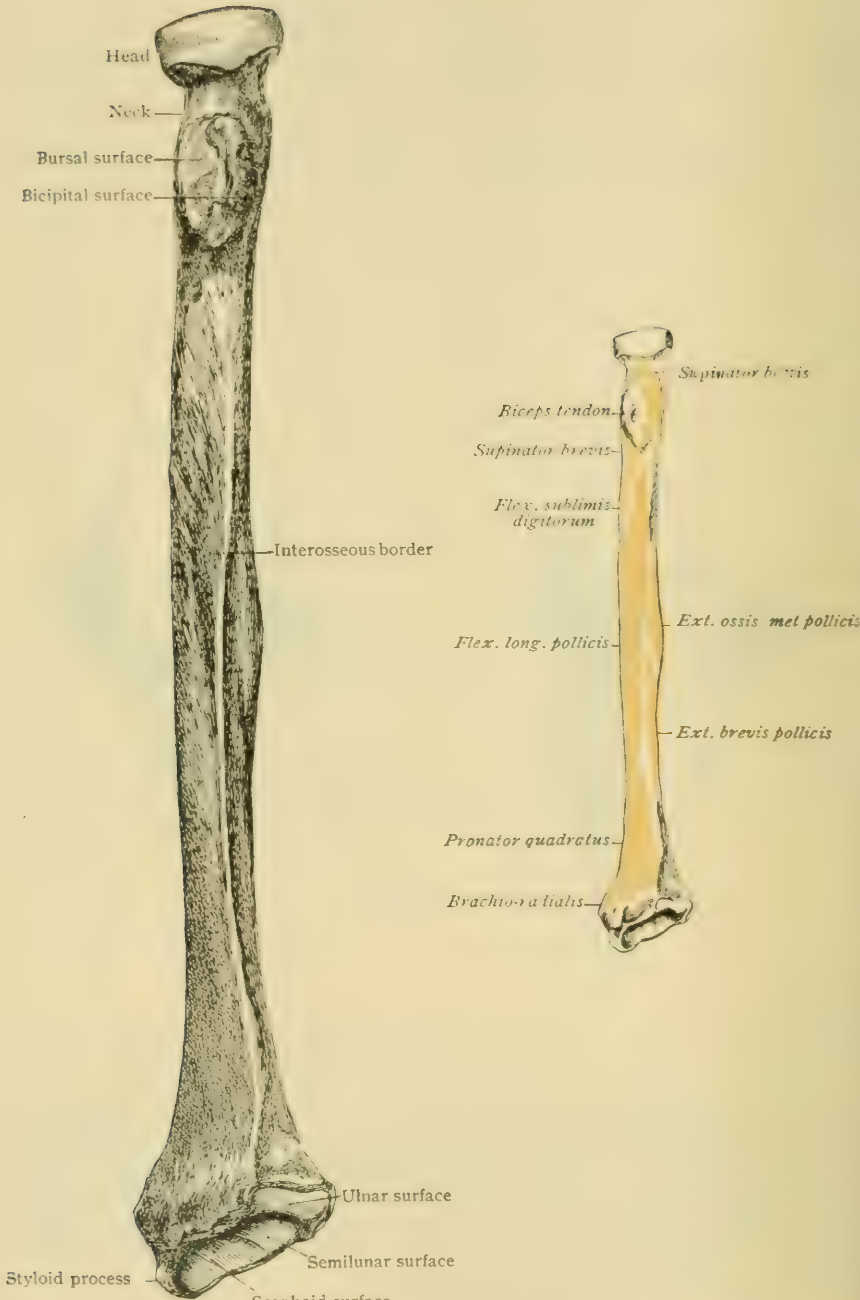
THE RADIUS.

The radius includes a shaft and two extremities.

The **upper extremity** consists of a head and neck. The **head**[1] is a circular enlargement with a shallow depression on top to articulate with the capitellum, and

[1] Capitulum.

FIG. 302.



Right radius, inner aspect. The outline figure shows the areas of muscular attachment.

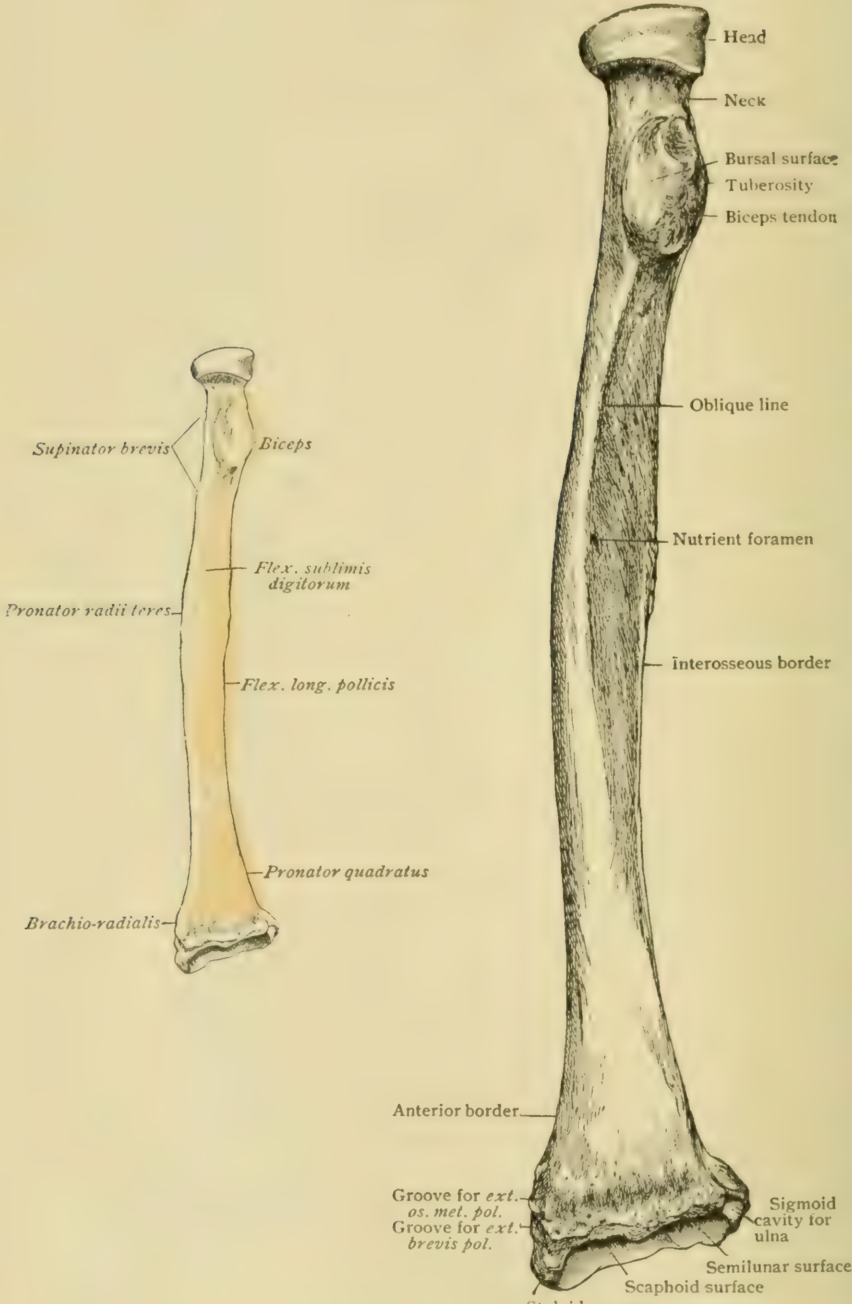
a smooth margin to turn in the socket formed by the lesser sigmoid cavity and the orbicular ligament, which completes it. The term "circular" is not used with mathematical precision, for slight variations from it are the rule. The most common one is an increase of the antero-posterior diameter. The depression on top is not symmetrical, for there is almost invariably a greater thickness of the rim in front, extending more to the inner than to the outer side. The smooth margin has a downward projection internally. The plane of the upper surface is not always at right angles to the axis of the neck, but often looks a little outward. The **neck** is a smooth constricted portion some two centimetres in length and approximately cylindrical.

The **shaft**[1] immediately bends outward below the neck, and has a slight forward curve at the lower end, where it broadens considerably. The *bicipital tuberosity*[2] is a large prominence at the inner and front aspect of the shaft, just below the neck. Its posterior border, which is rough and projecting, slants forward and receives the biceps tendon. In front of this the tuberosity is smooth for a bursa, lying beneath the tendon, which, in pronation, is rolled around it. The shaft is described as having three surfaces separated by three borders ; there is convenience in retaining the plan, although only one border is always distinct and one is almost imaginary. The distinct border is the *internal* or *interosseous*,[3] which, starting from the bicipital tuberosity, soon becomes sharp for the interosseous membrane, and runs to the lower quarter of the bone, where it divides into two descending lines to the front and back of the articular facet on the inner side of the lower end. The *anterior border*[4] which is generally distinct above, starts from the front of the tuberosity and runs downward and outward to about the middle of the bone. This part is known as the *oblique line* of the radius, which gives origin to a part of the flexor sublimis digitorum, and separates the insertion of the supinator brevis from the origin of the flexor longus pollicis. The border is thence poorly marked till, slanting forward to the beginning of the lower fourth, it becomes a distinct ridge running to the front of the styloid process and receives the insertion of the pronator quadratus. It broadens at the end into a triangular tubercle for the insertion of the brachio-radialis. The *posterior border* is important only as helping to define the posterior and outer surfaces ; it is usually to be seen in the middle third of the bone, and has neither a definite beginning nor end. The *anterior surface*, limited above by the oblique line, is slightly concave, and gives origin to the flexor longus pollicis as far down as the last quarter, which is slightly hollowed for the pronator quadratus and sometimes separated from the upper part by an oblique ridge. The *nutrient foramen* is seen above the middle, running upward. The *outer surface*, which is convex, presents about the middle a *roughness* for the insertion of the pronator radii teres. The *posterior surface* has a concavity in the middle third, internal to the posterior border, and is convex both above and below.

The **lower extremity** bends slightly forward, ending in front in a prominent ridge to which the capsule is attached. The outer side is prolonged downward as the *styloid process*, ending in a blunt point. It usually shows grooves for the tendons of the extensors of the metacarpal bone and first phalanx of the thumb, which pass over it. The external lateral ligament of the wrist arises from it. The posterior surface has a groove at its edge for the capsule, and above this is furrowed for the passage of certain tendons. Next to the styloid process is a broad depression, sometimes faintly divided into two, for the extensores carpi radialis longior et brevior ; internal to this is a marked ridge, the *tubercle*, slanting downward and outward, with a narrow, deep gutter beyond it for the tendon of the long extensor of the thumb. A very slight border separates this internally from a broad, shallow groove for the tendons of the extensor communis and that of the index-finger. At the extreme limit of the posterior surface is sometimes a minute furrow for a part of the tendon of the extensor of the little finger, which passes over the radio-ulnar joint. The inner side of the lower end is occupied by a concave articular area, the *sigmoid cavity*[5] of the radius, which receives the head of the ulna and much resembles the lesser sigmoid cavity of that bone. The lower surface is articular for the scaphoid and semilunar bones of the wrist. It is in the main triangular, the base being the inner side. It is overhung both before and behind, and is continued onto the

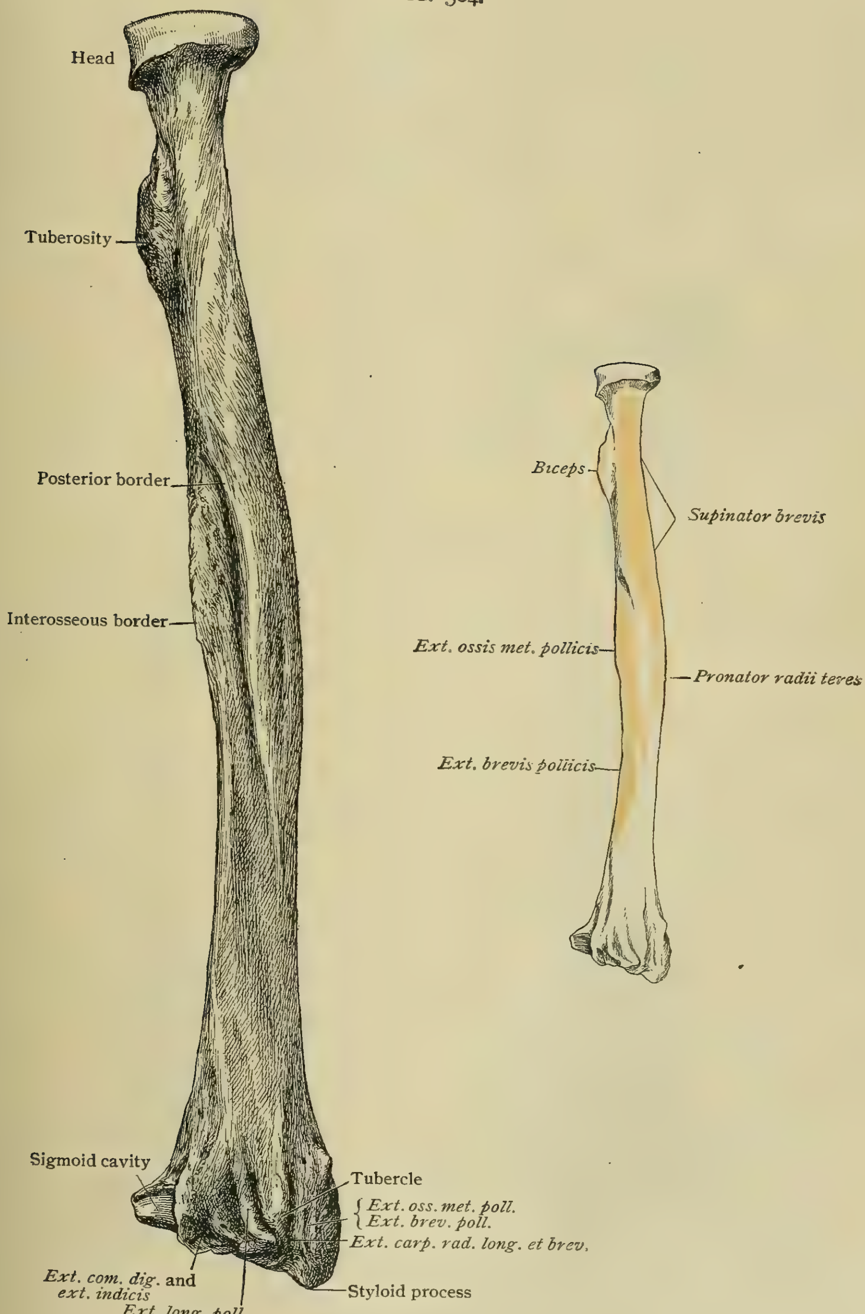
[1] **Corpus.** [2] **Tuberositas radii.** [3] **Crista interossea.** [4] **Margo volaris.** [5] **Incisura ulnaris.**

FIG. 303.



Right radius from before. The outline figure shows the areas of muscular attachment.

FIG. 304.



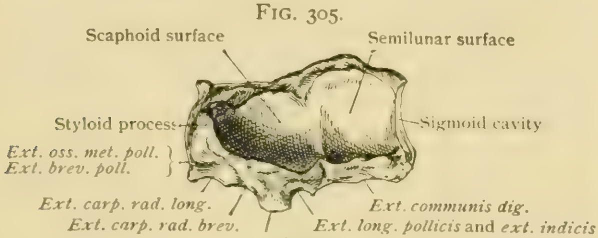
Right radius from behind. The outline figure shows the areas of muscular attachment.

inner side of the styloid. A faint ridge from before backward, beginning at a slight notch, marks off an inner square surface for the semilunar and an outer triangular one for the scaphoid. The surface looks slightly forward, thus causing the forward rising of the hand from the forearm.

In man the ulna is evidently the more important bone at the elbow and the radius at the wrist. In mammals below primates they are often more or less fused and the upper end of the radius relatively larger than in man. It often occupies the front of the elbow-joint, being anterior instead of external to the upper end of the ulna.

Structure.—The radius, like the ulna, is thick-walled through the greater part of the shaft. The tuberosity is composed internally chiefly of longitudinal

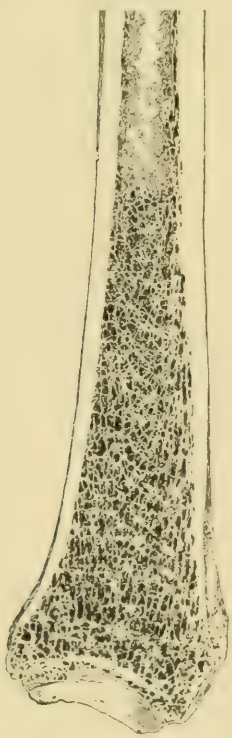
FIG. 305.



Lower end of right radius.

FIG. 306 *A*.

FIG. 306 *B*.

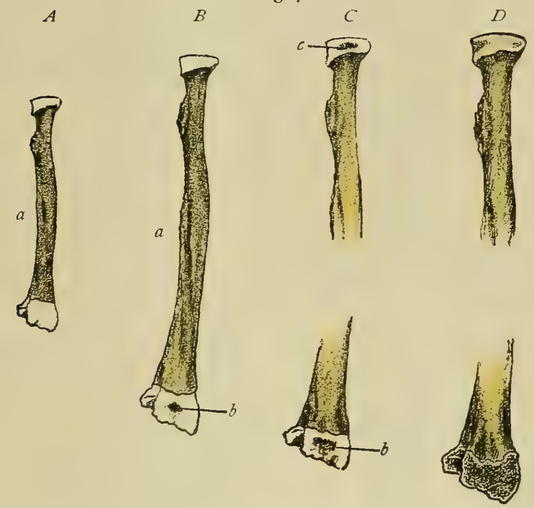


Longitudinal sections of radius; *B* in frontal plane, showing arrangement of trabeculæ in lower end of bone.

plates. A frontal section of the lower end of the radius shows the walls splitting up into longitudinal plates, which run to the lower end, connected by a system of lighter transverse ones.

Development.—The centre for the shaft appears at the end of the second month, and forms the whole bone, except the lower end and the head. The nucleus for the former appears at the end of the second year and that for the head at the

FIG. 307.



Ossification of radius. *A*, at birth; *B*, at two years; *C*, at five years; *D*, between eighteen and nineteen years. *a*, centre for shaft; *b*, for lower epiphysis; *c*, for upper epiphysis.

end of the fifth. The latter unites at about fifteen, the lower at eighteen or nineteen. A scale-like epiphysis for the bicipital tuberosity is said to appear towards eighteen and to fuse very promptly.

PRACTICAL CONSIDERATIONS.

The radius may be absent or more or less defective, and in either case there is apt to be corresponding absence or deficiency in the hand (Humphry).

As might be expected, injuries of the upper end in the adult are extremely rare. Except at one point (just below the external condyle posteriorly), the head is far from the surface and deeply buried beneath the thick supinators and the long and short radial extensors of the carpus. Even at that point, more prominent bony processes—the external condyle and the olecranon—receive the brunt of the injury in cases of falls or blows.

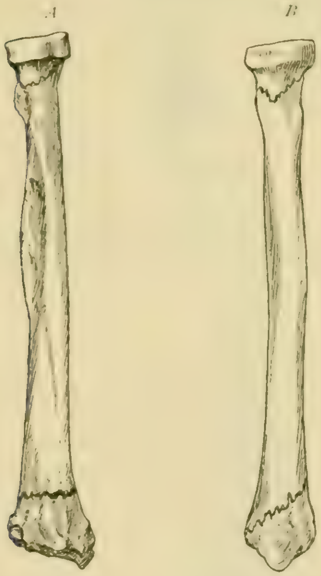
The upper epiphysis does not become fully ossified until the fifteenth year, and is united to the diaphysis at the beginning of the sixteenth year. It is, therefore, among the last of the epiphyses of the long bones to ossify and the first to join its diaphysis. The violence which separates it from the shaft is often direct. In cases of indirect violence the force is applied usually as a combined pull and twist on the forearm of a very young child. As the epiphysis is altogether intra-articular (the synovial membrane lining the whole inner surface of the orbicular ligament), swelling is early and marked. As there is direct communication with the larger synovial cavities of the elbow, the whole joint will participate in the effusion.

Although no ligaments or tendons are attached to the epiphysis, the orbicular ligament hugs it closely and holds it in place. If any displacement occurs, the upper part of the diaphysis may go either forward or backward. On movements of pronation and supination, the epiphysis can be felt immovable just below the external condyle.

An injury known as "elbow-sprain," or "pulled elbow," and described as a "subluxation of the orbicular ligament" and as a "subluxation of the head of the radius," should be mentioned here because, although it has been known for more than two hundred years, has well-defined and constant symptoms, occurs in one

per cent. of all surgical cases in children under six years of age, and is believed to depend on a distinct anatomical lesion, the exact nature of that lesion is still unknown. It is usually caused by traction on the forearm. The most plausible of many theories are: (1) that it is due to the head of the radius slipping out from beneath the orbicular ligament, which is pinched between it and the capitellum (Fig. 311); and (2) that it is a partial epiphyseal separation. The differential diagnosis is said to depend chiefly on the facts that in the "subluxation" the head of the radius will rotate with the shaft, and that all the symptoms disappear rapidly after forced supination has removed the functional disability. There seems nothing absolutely inconsistent with these symptoms in the view that a slight epiphyseal separation has occurred, the upper end of the diaphysis being displaced forward, but carrying with it the radial head. This theory is strongly favored by the fact that very few cases have occurred in children over five years of age. Ossification of the radial head begins towards the end of the fifth year. It should be remembered that the epiphysis includes only the upper part of the head, the lower portion and the neck being ossified from the shaft. The upper end of the diaphysis is therefore approximately of the same size and shape as the head, and may easily have been mistaken for it in many of the cases. The problem presented is so purely an anatomical one that, in spite of the prevalent differences of opinion, it seems proper to make this brief presentation of it.

FIG. 308.



Lines of fracture of neck and of lower end of radius (Colles's fracture). *A*, dorsal; *B*, lateral aspect.

Fractures of the head are uncommon. Fractures between the head and the lower end will be considered in reference to the effect of muscular action upon them (page 604).

In the neighborhood of the tubercle the thickness of the bone, the ridges that run up towards the head and down towards the outer edge, and the ample covering of muscles render fracture comparatively uncommon. A little lower the union of the two secondary curves near the point of greatest curvature in the primary curve of the whole shaft renders the bone more vulnerable. Still lower the effects of indirect violence through falls upon the hand, the union near the lower end of the compact tissue of the shaft with the cancellous tissue of the expanded lower extremity, the comparatively superficial position of the bone, and the projection of the anterior articular lip, into which the anterior carpo-radial ligament is inserted, all very markedly favor fracture.

Accordingly, we find that, on account of these anatomical conditions, of one hundred fractures of the radius, approximately, three will be in the upper third, six in the middle third, and ninety-one in the lower third, the large majority of these latter being within from 2.5 to 5 centimetres (one to two inches) of the wrist-joint.

Fractures of the lower end of the radius are almost always produced by a cross-breaking strain caused by falls on the hand, and exerted through the strong anterior common ligament. The broad attachment of this ligament to almost the whole anterior lip of the radius brings the strain equally on the bone through its entire width. The fracture is, therefore, usually irregularly transverse. In addition to the force transmitted by means of the ligament, there is an approximately vertical force, due to the weight of the body, which thrusts the sharp lower end of the shaft into the lower fragment, made up chiefly of spongy tissue, with merely a thin shell of compact tissue holding it together. This vertical force transmitted through the forearm

and hand not only thus impales the lower fragment on the upper, but necessarily carries the former to a higher level. In addition, the ulno-carpal fasciculus of the common ligament drags on the lower end of the ulna, and either causes fracture of the styloid process, into the side and base of which it is attached, or causes the lower end of the ulna to project unduly on the antero-internal aspect of the wrist. The stripping up of the periosteum, the laceration of the tendon sheaths that are so closely applied to the bone,—especially the flexor tendons by the jagged edge of the upper fragment,—and the consequent effusion are the chief remaining anatomical factors in producing the characteristic deformity of this most common of all fractures. The lower fragment is found on the dorsum of the wrist. The lower end of the upper fragment is found anteriorly beneath the pronator quadratus or under the flexor tendons (Fig. 586). The styloid process of the radius is on a higher level than that of the ulna; in dislocation of the wrist this is not the case. The hand is carried towards the radial side (Fig. 309).

FIG. 309.

Fracture of lower end of radius, showing hand carried towards the radial side.

In cases with but very trifling displacement it is still possible to recognize the absence of the projection of the anterior articular lip of the bone on the front of the wrist, and some slight elevation of the dorsum. The angle between the axis of the forearm and the ground is said (Chiene) to determine whether in such a fall the line of force passes upward in front of the axis of the forearm and the radius is broken, or extends up the forearm itself, resulting in a sprain of the wrist or a dislocation of the bones of the forearm backward at the elbow. The forward sloping of the carpal surface of the radius causes the posterior edge of the bone to receive the greater part of the force; hence the lower fragment is rotated backward on a transverse axis, and hence the disappearance of the prominence of the anterior articular lip. The carpal surface of the radius also slopes downward and outward; hence the radial edge of the lower fragment receives (through the ball of the thumb) a greater part of the shock than the ulnar edge, which is, moreover, firmly attached by the triangular ligament. This favors the upward displacement of the radial styloid and the radial displacement of the hand. There are almost always some crushing and distortion of the lower spongy fragment, even when it is not materially displaced.

Anterior displacement of this fragment may occur when the force is applied in the reverse direction,—*i.e.*, with the hand in forced palmar flexion. The infrequency of falls on the back of the hand explains the rarity of this accident, but the greater weakness of the posterior ligament and the absence of any projecting articular lip to increase the leverage exerted through the ligament also contribute to make the accident uncommon.

The later results of these fractures are much influenced by the close proximity of the flexor and extensor tendons to the region of injury, as, even when the sheaths escape laceration originally, they are liable to become adherent during the process of repair.

The lower epiphysis of the radius is osseous about the end of the tenth year and is united to the shaft in the nineteenth or twentieth year. The epiphyseal line is almost transverse (Fig. 310), and extends from about nineteen millimetres (three-fourths of an inch) above the apex of the styloid process to six millimetres (one-fourth of an inch) above the lower edge of the sigmoid cavity. The epiphysis is

thinnest in the centre (five millimetres), the line at that point crossing the bone about three millimetres below the tip of the prominent middle thecal tubercle.

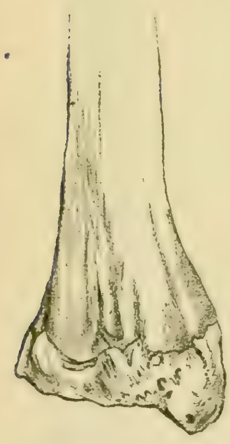
The need for an accurate conception of this epiphysis is emphasized by the facts: (1) that it is more often separated than any other in the body, with the possible exception of the lower epiphysis of the femur; (2) that its line has more than once been figured and described as a line of fracture on the basis of skiagraphs.

The cause of separation is almost always a fall on the pronated hand. The carpal bones are carried against the posterior border of the radial epiphysis, the pronator quadratus and other muscles fix the lower ends of the diaphyses of the radius and ulna, and the epiphysis is forced backward. The anterior carpal ligament and the tendons on the palmar surface of the wrist are put on the stretch and aid in the displacement. The supinator longus is directly attached to the epiphysis and aids in maintaining the deformity.

The synovial membrane of the wrist-joint does not reach the level of the epiphyseal line of either the radius or the ulna. That joint is, therefore, not frequently involved.

The thinness of the centre of the epiphysis would lead to the expectation that fracture would often complicate the separation. This is not the case, however. Poland says that the epiphysis is more solid than the lower end of the bone of the adult (which has, of course, become cancellous in structure), and that it thus escapes the fracture, comminution, and impaction which are so frequent in later life.

FIG. 310.



Lower end of left radius, showing epiphyseal line, dorsal aspect.

The radius is often the subject of rickets, and of both syphilitic and tuberculous epiphysitis, especially at its lower end, on account of the exceptional frequency of falls upon the hand and strains of the epiphyseal joint.

Subperiosteal sarcomata are rare. Central sarcomata almost invariably attack the lower end of the bone (page 366).

Landmarks.—The head of the bone may be felt at the bottom of the dimple or depression just below the external condyle and to the outer side of the olecranon. It lies between the outer border of the anconeus and the muscular swell of the supinator longus and radial extensors of the carpus. It is covered by the external lateral and orbicular ligaments. It can readily be felt to move when the forearm is pronated and supinated. Its presence in that position demonstrates that dislocation of the radius or of both bones of the forearm backward—the common dislocation at the elbow—has not occurred. Its free rotation negatives the existence of a non-impacted fracture of the radius.

The upper edge of the head lies immediately below the elbow-joint. In full supination the tubercle can be indistinctly felt a little below the lower edge of the head. The upper half of the radial shaft cannot be felt, as it lies beneath the bellies of the extensors and the supinator brevis. The lower half is almost subcutaneous and can readily be palpated through or between the tendons and muscles. The expanded lower extremity is partly subcutaneous (at the base of the styloid externally) and is readily felt. The styloid itself, the prominent tubercle at the radial side of the groove for the extensor longus pollicis (middle thecal tubercle), and the sharp tubercle at the base of the styloid can easily be recognized. The latter is the inferior termination of the pronator crest of the diaphysis, marks the external termination of the epiphyseal line, and is on a level with the lower and outer part of the pronator quadratus muscle. The posterior end of the middle thecal tubercle is three millimetres above the epiphyseal line on the posterior aspect of the bone.

The styloid process of the radius is lower—*i.e.*, nearer the hand—than the styloid process of the ulna.

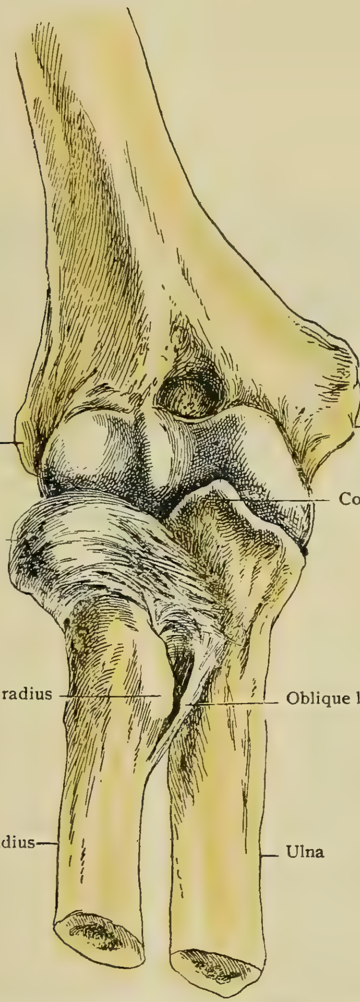
JOINTS AND LIGAMENTS BETWEEN RADIUS AND ULNA.

These include,—

1. Superior Radio-Ulnar Articulation :
   Orbicular Ligament ; Capsular Ligament.
2. Inferior Radio-Ulnar Articulation :
   Triangular Cartilage ; Capsular Ligament.
3. Ligaments uniting the Shafts :
   Interosseous Membrane ; Oblique Ligament.

The **superior radio-ulnar joint**[1] (Figs. 311, 312) is between the circumference of the head of the radius and the lesser sigmoid cavity of the ulna extended into a circle by the orbicular ligament. The articular ends of the bones are coated

FIG. 311.



Superior radio-ulnar articulation, anterior aspect. The capsule of the elbow has been removed.

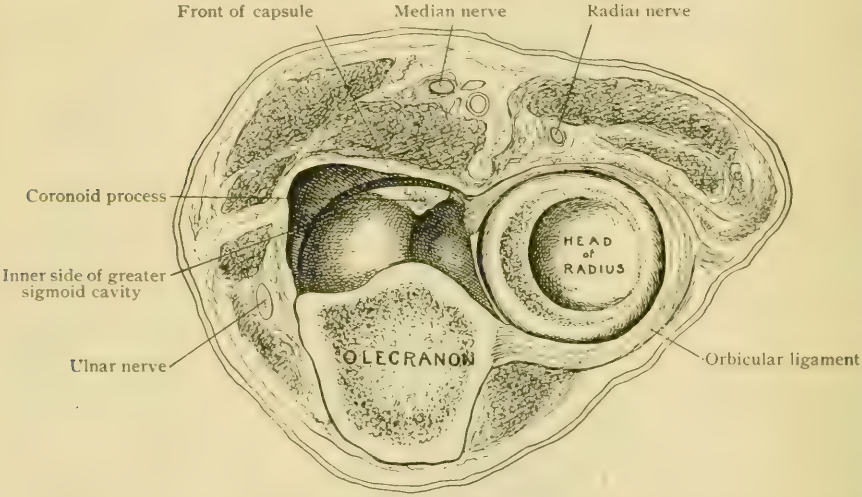
with cartilage requiring no particular description. The **orbicular ligament**[2] (Fig. 311) surrounds the head of the radius, springing from the two ends of the lesser sigmoid cavity and from the lines running down from them. This band embraces the head tightly, but is separated from it by the cavity of the joint, and is lined with

[1] Artic. radioulnaris proximalis. [2] Lig. annulare radii.

synovial membrane. It narrows below so as to fold under the projecting head, and is attached, chiefly through fibres from the lower border of the lesser sigmoid cavity, to the inner side of the neck. It is connected above with the **capsular ligament** of the elbow-joint. That the fibres to the neck limit rotation is easily shown by dividing all bands connecting the bones, excepting the orbicular ligament: for were it not so, the radius could then be turned continuously, which is not the case. It is doubtful, however, whether these fibres become tense by any movement which can occur in the undissected joint.

The **inferior radio-ulnar joint**[1] is, when seen from the front, an L-shaped cavity, the vertical part being between the head of the ulna and the hollow on the radius, and the horizontal limb between the ulna and the **triangular cartilage,**[2] which is attached by its base to the border between the inner and lower ends of the radius in such a manner that its distal surface is in the same plane as the lower end of the radius. The apex of the cartilage is attached by a ligament some three millimetres long to the groove between the head and the styloid process of the ulna and to the inner surface and anterior edge of the latter. Strong bands, inseparable from the ligaments of the wrist, run along its border to the front and back of the articular surface of the radius. The fibro-cartilage is very flexible

Fig. 312.



Horizontal section through right elbow-joint from above. The trochlea of humerus has been removed.

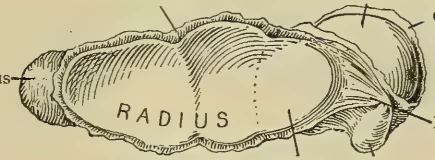
and adapts itself to the surfaces of the lower end of the ulna and of the first row of the carpus. Its inner end, however, is not as broad as the lower end of the ulna. It is in some cases perforated. The **membrana sacciformis** is the synovial membrane of this joint, lining the capsule between the ulna and the triangular cartilage, between the ulna and radius, and extending a little above the level of the top of the apposed articular surfaces of these bones. The **capsule** enveloping it is delicate, but strengthened in front and behind by ill-marked bands passing between the bones; these are sometimes described as distinct *anterior* and *posterior ligaments.* The connection between the lower ends of the bones is much strengthened by the pronator quadratus.

The **ligaments between the shafts** are the interosseous membrane and the oblique ligament. The **interosseous membrane**[3] (Fig. 315), composed of fibres running downward and inward, closes, except above, the opening between the bones. Beginning from one to two centimetres below the tubercle of the radius on the anterior surface of the interosseous ridge, and lower from the sharp edge, it connects the two ridges as far as the lower joint, following the posterior division of the interosseous ridge of the radius. The upper fibres are nearly transverse. Some long fibres, particularly on the posterior surface, run from ulna to radius. There are

[1] Artic. radioulnaris distalis. [2] Discus articularis. [3] Membrana interossea interbrachii.

several small openings for the passage of vessels and nerves. Pressure transmitted upward from the hand through the radius would tend to stretch the greater number of the fibres, and thus distribute the strain through both bones. While the radius

FIG. 313.

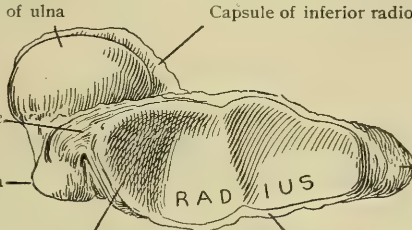


Lower end of right radius in supination.

can hardly be enough displaced to bring this about, it is conceivable that the bones might bend sufficiently to make this action effective.

The **oblique ligament**[1] (Fig. 311), an inconstant little band, runs downward and outward, partly closing the space above the membrane. from the tubercle of the

FIG. 314.



Lower end of right radius in pronation.

ulna to the beginning of the oblique line of the radius. It has been plausibly suggested that it represents a part of the flexor longus pollicis muscle.

THE FOREARM AS A WHOLE, AND ITS INTRINSIC MOVEMENTS.

The two bones and the ligaments form an apparatus capable of being moved as a whole on either the arm or the hand, and of greatly changing its own shape by the movements of the radius on the ulna. As these latter are theoretically independent of the position of the forearm with regard to the arm, it is best to consider them here.

The movement of the radius is a very simple one of rotation on an axis coinciding with that of the neck of the bone, and then, owing to the outward bend of the shaft, passing down between the bones and finally through the head of the ulna. The amount of rotation probably rarely exceeds 160°. Rotation is limited chiefly by the anterior and posterior radio-ulnar ligaments, the former being very tense at the end of supination and the latter at the end of pronation. The oblique ligament limits forced supination. As above stated, it is unlikely that the fibres of the orbicular ligament to the radius become tense during life. The fact that the lower end of the radius swings round the ulna in no way changes the character of the movement. If the radius were throughout in continuation of the axis of the neck, and the ulna enlarged below to support it, rotation on the axis of the neck would not change the position of the bone. The departure of the greater part of the radius from that line necessitates the swinging round of the lower end, but does not affect the nature of the movement.

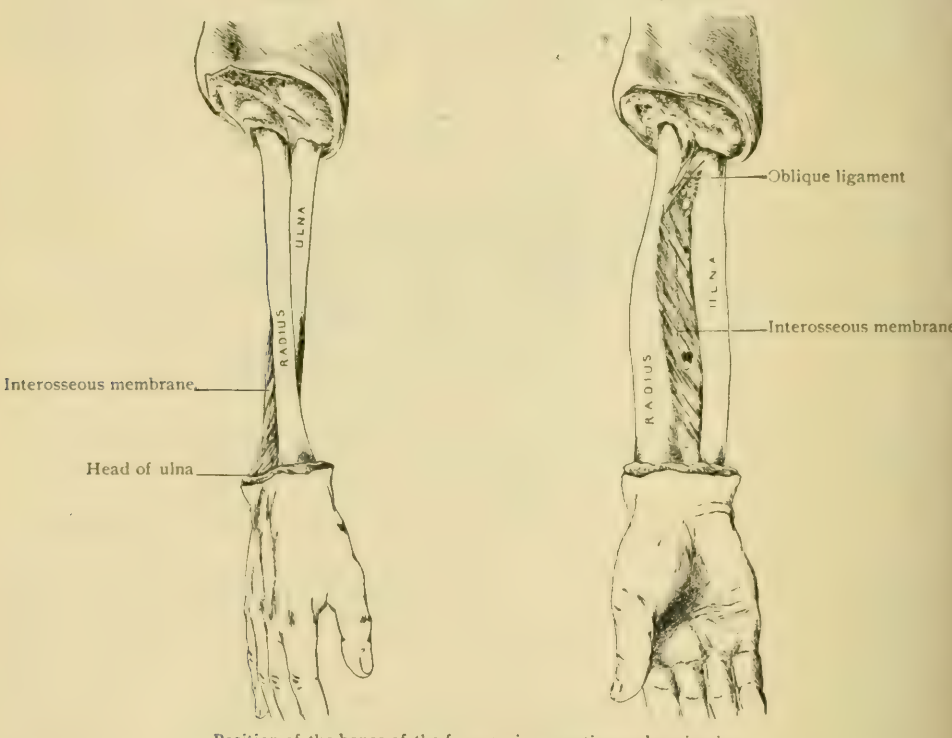
The changes of relative position of the bones during rotation are very important. It must be remembered that when the ulna is held so that the front of the middle of the shaft is horizontal, the head of the radius is in a plane above that of the main

[1] Chorda obliqua.

axis of the ulna. When the radius is brought into semipronation (so that the thumb will point upward) the bones are most nearly parallel and at the greatest possible distance from each other, and the membrane is approximately tense (Fig. 315). The forearm is broadest at about the middle. The membrane is at the bottom of a moderate hollow seen from either the front or the back. In extreme supination the anterior hollow is effaced and the posterior deepened. The radius approaches the ulna, especially above the middle. In extreme pronation the front hollow is much deepened and the hind one lost. The bones are much nearer together than in any other position. The radius crosses the ulna, and is above and internal to it at the wrist.

Should the capsule be opened from below without disturbing the triangular cartilage in a specimen from which the hand has been disarticulated, in supination the front of the under side of the head of the ulna will be exposed ; in forced pronation

FIG. 315.



Position of the bones of the forearm in pronation and supination.

almost the whole under end will appear (Figs. 313, 314). As the radius passes behind the head, the ligament of the triangular cartilage is relaxed and the band at the back of the joint is made tense. This ligament becomes tense before complete supination and is somewhat relaxed when supination is extreme.

The motion above described is the only one between the radius and ulna; nevertheless, in certain movements of twisting the hand and arm the ulna plays a part to be considered later (page 304).

Surface Anatomy of the Radius and Ulna.—The position of both bones can be felt in a body that is not very muscular, though comparatively little of them is subcutaneous. The triangular space of the back of the olecranon, and the posterior border of the ulna starting from it and running to the styloid process, can all be traced with the finger. When the arm is straight, the top of the olecranon is a little above the level of the internal condyle and behind it ; when the arm is bent at a right angle, the top of the olecranon is in the same vertical plane as the back of

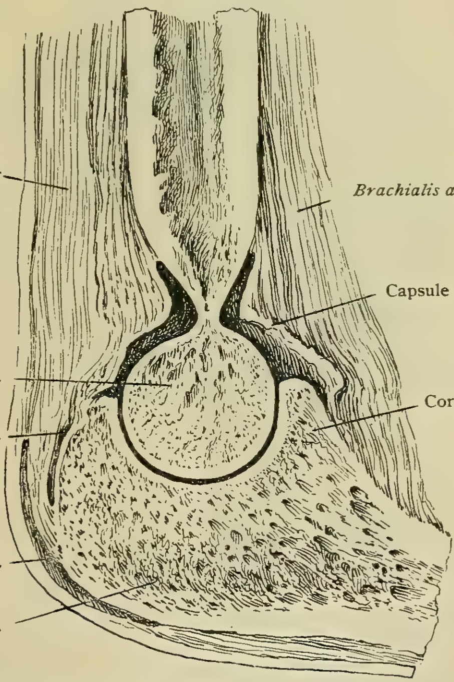
the humerus ; and when it is strongly flexed, the top of the olecranon corresponds to the vertical plane of the internal condyle. The head of the radius and the furrow above it opening into the joint are easily felt at the outside and behind. In the lower third of the forearm the bones can easily be felt. The ulna here is posterior and best felt at the back. In supination the styloid process is distinct. It is hidden by the soft parts in pronation, and the head is exposed. The forward sweep of the lower end of the radius is evident. The inferior expansion can be felt both before and behind ; the styloid process is examined best from the outer side. It extends nearly one centimetre lower than that of the ulna. The inequalities on the back can be felt vaguely ; the most evident is the ridge bounding the groove for the long extensor of the thumb.

THE ELBOW JOINT.[1]

This is a considerably modified hinge-joint, the axis of rotation being oblique to the long axis of both the humerus and the ulna, and the course of the latter at the joint being also a spiral one. It is to be understood that the radius follows the ulna, which is the directing bone of the forearm in the motions of the elbow.

The Articular Surfaces.—These have been described with the bones ; it remains only to give here a summary. The motions between the forearm and the humerus depend essentially on the trochlea and on the surfaces of the greater sigmoid cavity. This is a modified hinge-joint. As has been shown, the transverse axis of

FIG. 316.



Sagittal section of right elbow-joint through the trochlea.

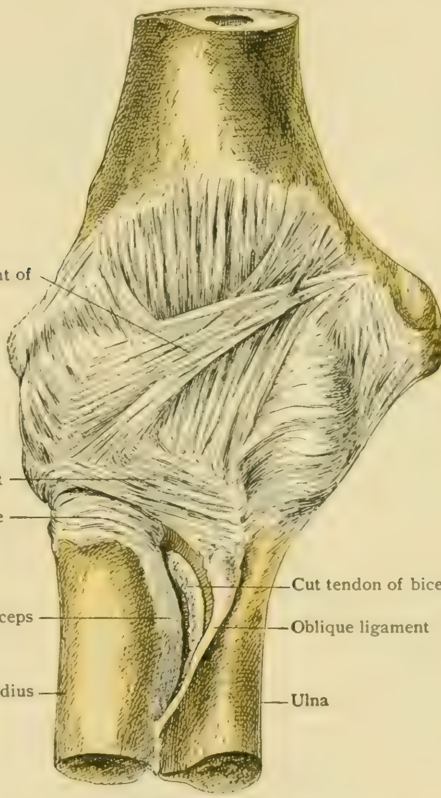
the trochlea is not at right angles to the shaft, and it may be added that the same is true of the sigmoid cavity and the axis of the ulna. The effect of this will be noticed later. Again, as already pointed out, the trochlea is not only oblique, but is so shaped that the ulna in turning on it describes a spiral line. It has also been shown that the trochlea is not equally broad throughout, and that there are curious differences of curve in the sigmoid cavity. Finally, the lateral ligaments are not quite tense, especially when the joint is half flexed. It follows from these facts that the motion is a very complicated one, and that a certain lateral motion of the ulna on

[1] Articulatio cubiti.

the humerus is possible. The head of the radius plays on the capitellum, but it follows the ulna.

The **capsular ligament**[1] surrounding the joint is very weak behind, stronger in front, and very strong at the sides, which last-named parts are usually called the *lateral ligaments.* The *anterior fibres* arise from the humerus above the coronoid and radial fossae, and from the front of the bases of both condyles. Behind, they arise from about the middle of the olecranon fossa, which is only partly within the capsule. Transverse fibres bridge it, passing between the highest points of the borders of the trochlea. Below this the *posterior fibres* arise beyond these borders, so that the trochlea is included in the joint. At the sides the fibres forming the so-called *lateral ligaments* radiate from points below the tips of the condyles. A little of the external and a large part of the internal condyle are not enclosed. The

FIG. 317.



Capsule of right elbow-joint from before.

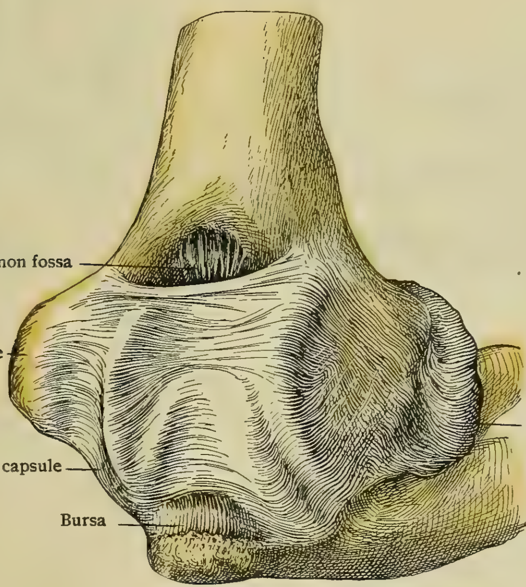
capsule is inserted below, posteriorly, into the little groove described with the bone at the border of the olecranon. The radiating fibres from the external condyle are inserted into the surface of the orbicular ligament, behind, outside, and in front. They are covered by tendinous fibres of the muscles from the condyle, which are almost inseparable from them, and which greatly strengthen the joint. The fibres radiating from the tip of the inner condyle, or the *internal lateral ligament,*[2] are in two layers. The posterior, the deeper, is attached to the side of the olecranon; the anterior is a strong band passing to the side of the coronoid process, which sends fibres backward, overlapping the deeper layer. The anterior fibres go to the orbicular ligament and to the coronoid process near its edge. The front part of the capsule is strengthened by delicate oblique fibres from the front of the internal condyle, passing downward and outward. Masses of fat, incorporated in the capsule both before and behind, project into the joint, carrying the synovial membrane before

[1] Capsula articularis. [2] Lig. collaterale ulnare

them. There is a thick pad of fat, which, when large, may bear well-marked synovial folds at the notch on the inner side of the ulna where the olecranon joins the coronoid.

Movements.—These are of two orders: that of flexion and extension, and those which occur in twisting the forearm. For practical purposes the former may be reduced to those of the ulna, which the radius is forced to follow. The movements of the ulna are not far from turning on an oblique axis, which cuts the long axis of the humerus at an angle of approximately 80° externally. When the forearm is fully extended, it therefore forms externally an obtuse angle with the humerus. Were the long axis of the ulna perpendicular to the axis of the joint, the forearm in flexion would cross the humerus, as indeed is often erroneously stated; in fact, however, the long axis of the ulna also forms an angle of about 80° with the axis of the joint, and, as these angles equal each other, in flexion the forearm is parallel with the humerus. A simple demonstration of this is gained by cutting out a copy of Fig. 320.[1] On folding it at the line of the joint (*a b*) the two parts will lie one on

FIG. 318.



Right elbow-joint, posterior and outer aspect.

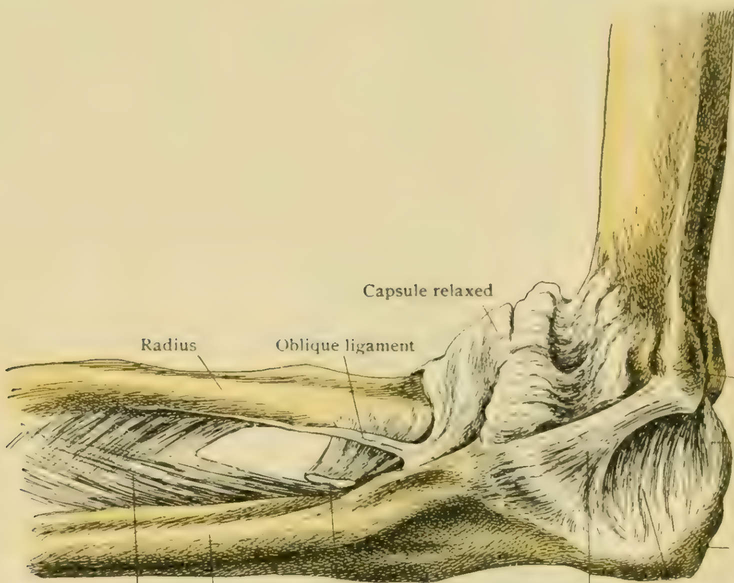
the other. If then another model be made with the axis of the lower piece at right angles to the joint, it will show that the lower piece crosses the upper. When extension is complete, the tip of the olecranon can go no farther into the fossa on the back of the humerus, and the front of the capsule is tense. In complete flexion of the dissected arm, the tip of the coronoid is in contact with the humerus in front; but in life the motion may be checked by the soft parts before it has reached its limit. Morris has shown that there is much variation in the range of movement, depending on differences in the upper end of the ulna. The lateral ligaments of a theoretically perfect hinge-joint should always be tense; in the elbow they are not quite tense in semiflexion. Moreover, the imaginary axis does not remain fixed throughout the motion.

Motions of the Forearm on the Humerus in twisting the Hand.—The articulation between the concave head of the radius and the convex capitellum of the humerus is practically a ball-and-socket joint; the radius may glide on the humerus, following the ulna, or it may rotate on a fixed axis, as described above. It is easily shown, however, that the swinging of the lower end of the radius round

[1] Potter: Journal of Anatomy and Physiology, vol. xxix., 1895.

a motionless ulna is not what actually occurs in life. Let the reader grasp lightly his right wrist with his left thumb and forefinger, so that they nearly meet at the styloid process of the radius, and, pressing the right elbow to the side for steadiness,

FIG. 319.



Right elbow-joint, inner aspect.

pronate the right arm. The lower end of the radius will occupy the place at the base of the left thumb previously occupied by the ulna, which will have travelled outward along the left forefinger. It is very doubtful whether in this experiment all motion at the shoulder is eliminated ; nevertheless, the ulna undoubtedly changes its place, and with equal certainty it does not "rotate." To prove this, let the arm of a subject be held in a vice above the elbow, which should be semiflexed, and, the forearm being supine, let a long pin pointing outward be fixed into the outer side of the radius above the wrist, and another pointing inward into a corresponding point of the ulna. On pronating the hand, the pin in the radius will describe a large curve and that in the ulna will make no evident movement. On close inspection, aided by placing some object close to the head of the pin in the ulna, it will appear that, though the bone has not rotated, the pin-head has changed its place : it has moved downward and outward. If the hand be now disarticulated, and two pins bearing brushes dipped in paint be placed in the end of the head of the ulna and in the lower surface of the radius, pointing downward so as to continue the line of the shafts of these bones, on twisting the forearm, each of these brushes will describe a curve on a sheet of paper held against them ; that in the radius making a large curve upward and inward, and the ulnar pin a small one downward and outward. The relative size of these curves may be varied greatly by the operator. What has occurred is this : besides the rotation of the radius, there has been a lateral movement between the ulna and humerus combined with a slight extension. This movement is less when the arm is nearly straight than when flexed, for in the latter position the lateral parts of the

FIG. 320.

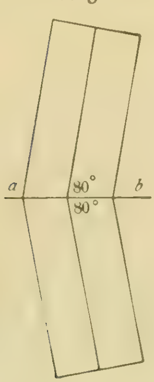


Diagram showing the equal angles of the long axes of the bones with the axis of the joint.

capsule are least tense. It is probably assisted by a want of perfect adaptation between the articular surfaces. These experiments on the dead body do not quite fulfil the conditions of the living, because we have no evidence that then the muscles can produce quite the same movement; moreover, Cathcart has shown that in ankylosis of the shoulder-joint this motion is greatly impaired, thus proving that in life a small amount of motion at that joint is an essential part of free twisting of the hand. Experiments by Hultkrantz on the living subject tend to show that the slight motion of the ulna is in the opposite direction to that described. There is probably much individual variation.[1]

PRACTICAL CONSIDERATIONS.

The Elbow-Joint.—This joint is dependent for its strength more upon the shape of the bones that enter into it than upon the ligaments or muscles. As the elbow ceased to be useful for support, but became of the utmost importance for prehension, the radius became movable instead of fixed, and the strength of the joint came to depend in much larger proportion upon the ulna.

Force applied in the line of the long axis of the limb, as in hanging by the hands (the weight being transferred from the wrist and the radius to the ulna and the elbow, largely by means of the triangular and orbicular ligaments, with very slight help from the oblique ligament), is resisted in the order of effectiveness (*a*) by the hook of the olecranon over the trochlea; (*b*) by the lateral ligaments; (*c*) by the biceps, triceps, and brachialis anticus, aided by the flexors, extensors, pronators, and supinators. The lower part of the lesser sigmoid cavity of the ulna underhangs the inner edge of the radial head, and aids in preventing the radius from being drawn away from the ulna.

Force applied in the same line, but in the opposite direction, as in falls upon the hands (the thrust being transferred from the radius to the ulna by means of the oblique fibres of the interosseous membrane), is resisted almost exclusively by the coronoid process, aided perhaps by the surface of contact between the radial head and the capitellum, which is diminished in full extension.

As the dislocation usually occurs with the forearm hyperextended, the lateral ligaments, particularly the inner one, are often stretched and torn; the brachialis anticus is drawn tightly over the humerus and is sometimes ruptured. The coronoid process is not infrequently broken.

Antero-posterior dislocations are the most frequent, because of (*a*) the lesser antero-posterior diameter of the joint as compared with the lateral diameter; (*b*) the varying efficiency of the hold of the ulnar processes—the coronoid and olecranon—on the humerus in different positions of the elbow; (*c*) the weakness of the anterior and posterior ligaments, and the absence of effective muscular support.

Backward dislocation of both bones is far more frequent than forward, because: (1) The capsular ligament is weakest posteriorly. (2) The coronoid, which resists backward displacement, is smaller, less curved, and received in a shallower fossa than the olecranon, which prevents luxation forward. (3) It is in its relation of least effectiveness when the joint is in full extension. (4) Falls upon the hand with the forearm extended greatly outnumber all other causes of dislocation of the elbow. (5) In full extension the already slight surface of contact between the radius and humerus is diminished and the posterior articular edge of the radial head projects behind the capitellum. (6) The ulna and radius are apt to be dislocated together rather than separately because of the strong ligaments which hold them to each other—the triangular ligaments below, the interosseous membrane, and the orbicular and oblique ligaments above—and because of the absence of any such intimate connection of either bone with the humerus.

It is this ligamentous connection with the ulna which enables the radius, in spite of the shallowness of the articular cup upon its head, to resist the powerful forward pull of the biceps.

[1] Heiberg: Ueber die Drehung der Hand, 1884, contains an exhaustive bibliography. Heiberg: Journal of Anatomy and Physiology, vol. xix., 1885. Cathcart: ibid. Dwight: ibid. Hultkrantz: Das Ellenbogen Gelenk und seine Mechanik, Jena, 1897, contains the later bibliography.

Lateral dislocations of the separate bones are infrequent for the same reason ; of both bones because of the great relative width of the joint, its irregular undulating transverse outline, the prominences of the border of the trochlea and of the capitellum, the strength of the lateral ligaments, and the presence of the flexor and extensor muscular masses arising from the condyles.

Inward dislocation is the rarest on account of the greater projection of the inner border of the trochlea.

When either bone is dislocated *separately*, it is most apt to be the radius, and in the forward direction on account of the slightness of its humeral connection, its mobility, its direct relation with the hand and wrist, and the effect of muscular action (biceps) upon its upper extremity. The orbicular ligament offers the chief, if not the only resistance to this forward pull of the biceps. Therefore, if this is torn, recurrence of the luxation is common, unless the arm is kept in the acutely flexed position. When the ulna is dislocated alone, it is almost always backward for reasons already mentioned.

In the common backward dislocation of both bones, the tip of the coronoid may rest upon the posterior surface of the trochlea, or may ascend to the level of the olecranon fossa, which, however, it is prevented from actually entering by the presence of the soft parts and by the tension of the structures on the front of the joint. The most easily recognized symptom of this displacement is the change in the relation of the tips of the condyles and the olecranon, the latter occupying a much higher position in extension, or lying much more posteriorly in flexion (page 287, Fig. 301). In making this measurement it is important to be sure that the line uniting the tips of the condyles, and in full extension in the normal arm, crossing the olecranon about one-sixteenth of an inch below its tip, is a straight line at right angles to the long axis of the humerus. Any upward or downward curve given to this line destroys its diagnostic significance.

The large majority of cases of dislocation of the elbow occur in young males, usually below the age of twenty. Krönlein has called attention to the fact that at this age fractures of the clavicle are also common and luxation of the shoulder is rarely met with. while after twenty both clavicular fracture and elbow dislocation are comparatively rare and shoulder dislocation is common. He concludes that in childhood fracture of the clavicle is the equivalent of dislocation of the shoulder by direct violence, and dislocation of the elbow is the equivalent of the shoulder dislocation from indirect violence.

The anatomical explanation may be that the disproportion between the head of the humerus and the glenoid cavity (page 278) is less marked in childhood, the articular surfaces are therefore not so easily separated, and force applied to the point of the shoulder is more apt to reach and be expended upon the clavicle.

As to the elbow, the shallowness in children of the fossæ which receive the processes and a corresponding want of prominence in the latter, together with the ease with which the elbow-joint in childhood may be hyperextended (which is not the case in adult life), are possible explanations of the frequency of this dislocation in young persons.

Congenital dislocations occur. In some instances they have been associated with deficiency of the capitellum, and have then been accompanied by such elongation of the radial neck as to place the head of that bone on a level with the tip of the olecranon.

This affords an illustration of the general law, which may be mentioned here, that the rate of growth of epiphyses is inversely as the pressure upon them. Other examples are to be seen in the overgrowth of the cranial bones in hydrocephalus, when their edges are separated by the pressure of the ventricular fluid ; in the projection of the vomer and intermaxillary bones beyond the level of the alveolar arch in some cases of cleft palate ; in the bony outgrowths that fill up the glenoid cavity or the acetabulum in unreduced luxations of the humerus or femur ; and in many other similar conditions.

Disease of the elbow-joint is most often tuberculous, but may be of any variety. In spite of the constant exposure of the joint to traumatism, it is not attacked by disease with exceptional frequency. This is probably partly due to the firm inter-

locking of its bony constituents, preserving its ginglymoid character and preventing the injurious effect of side strains, partly to the similar protective effect of its strong lateral ligaments, and somewhat to the laxity of its capsule, permitting of moderate distention without undue tension. It is easily and often spontaneously immobilized in the early stages of disease ; it then bears no weight and is but little exposed to harmful increase of intra-articular pressure from muscular spasm ; and finally, as its fixation does not, as in the joints of the lower extremity, interfere greatly with moderate out-door exercise, the general resistant power is not so easily lowered. Swelling first shows itself posteriorly on either side of the olecranon process, and extends to the fossa over the head of the radius. In these directions the capsule is thinnest and most lax and the synovial cavity is nearest the skin. As distention continues there may be a bulging beneath the anconeus to the outer side of the olecranon, or on the front of the elbow beneath the brachialis anticus and extending towards the outer side, as it is limited internally by the thickening of the capsule constituting the internal lateral ligament.

Pus is apt to follow the same lines of least resistance, and discharge upon the back of the arm on either side of the triceps, but especially on the outer side on account of the attachment of the dense intermuscular fascia above the internal condyle ; over the head of the radius beneath the external condyle ; or in front to the outer side of the tendon of the biceps, a position determined by the resistance of the bicipital aponeurosis on the inner side.

The radio-ulnar joint, which is part of the articulation, is often involved, affecting the motions of pronation and supination.

The upper radial epiphysis and most of the lower humeral epiphysis are within the limits of the capsule, and may either be the starting-point of joint disease or become secondarily involved.

The position of semiflexion which gives the greatest ease, and is therefore voluntarily assumed, is that which affords most room for synovial distention and relaxes the muscles most immediately in relation with the joint. Distention of the joint is easily distinguished from disease of the neighboring bursæ. The bursa over the olecranon, when enlarged, constitutes a single rounded superficial prominence ; that beneath the triceps tendon, while it causes swelling on either side of that structure, does not extend to or obliterate the fossa over the head of the radius, nor does it cause a "puffiness between the inner condyle and the olecranon process when the arm is bent at a right angle" (Barwell). The bursæ beneath the brachialis anticus and between the tubercle of the radius and the biceps tendon, if enlarged, cause a vague fulness over those regions, but none of the characteristic appearances of synovitis. Chronic enlargement of the latter bursa, in a case of Agnew, caused pressure paralysis of the muscles supplied by the median and posterior interosseous nerves.

The obliquity of the line of the elbow-joint (page 268) should be remembered in the treatment of fractures involving the articulation. In obscure injuries about the joint the position of acute flexion, with the hand upon the front of the chest, is the one least likely to be followed by serious ankylosis, as in that position the full functional value of this obliquity is more apt to be preserved than when the forearm is at a right angle. The position is also the one in which it is easiest to retain in place many fractures in the region of the elbow. Especially in fractures of the lower end of the humerus, if the fragments are at once replaced, the coronoid process in front and the muscular and tendinous structures behind hold them firmly and prevent recurrence of deformity. If the fracture is intercondylar, or T-shaped, the acutely flexed position not only holds the condyles in position, but tends to prevent by pressure the involvement of the joint line by callus, which later would prove obstructive. If either the coronoid or olecranon fossa, or both, be involved, it is more important to prevent the filling up of the former than of the latter, as full flexion is of far greater functional importance than full extension. If the condyles—especially the inner—be split off, the position relaxes the muscles that cause displacement. It is also, of course, the most useful position of the limb in case ankylosis does occur.

In *excision* of the elbow-joint the following anatomical points should be remembered : (1) The lines of the various epiphyses. (2) The position of the ulnar nerve

in the groove between the internal condyle and olecranon. (3) The close relation of the posterior interosseous nerve to the head of the radius. (4) The post-operative value (in extending the forearm) of the outer aponeurotic expansion of the triceps and of the anconeus muscle. These should be carefully protected from injury.

Landmarks.—The following points may be mentioned in addition to those which may be found under the Humerus, Radius, and Ulna :

A line from one condyle to the other will be at right angles with the humeral axis, but will be oblique in relation to the axis of the forearm.

The line of the radio-humeral articulation is horizontal. The line of the humero-ulnar articulation is oblique downward and inward ; the tip of the internal condyle is therefore from a quarter to a half inch farther above the articular line than is the tip of the external condyle. The internal condyle points backward rather than inward.

The length of the articulation line is about two-thirds of the length of a line joining the tips of the condyles. In semiflexion the external condyle is easily seen ; in acute flexion it disappears, and the rounded capitellum of the humerus, with the outer edge of the triceps stretched over it, can be seen and felt.

The Inferior Radio-Ulnar Joint.—This articulation has been dislocated in a few instances, in most of which, the cause having been extreme pronation of the wrist, the lower end of the ulna was carried backward, projecting on the back of the wrist and pointing outward,—*i.e.*, towards the middle finger. The backward displacement probably involves the tearing of the triangular fibro-cartilage and a rupture of the posterior radio-ulnar ligament. The deviation of the ulna to the radial side may be due to the action of the pronator quadratus. The shallowness of the sigmoid cavity on the radius favors recurrence after reduction. But little is known of this injury.

THE HAND.

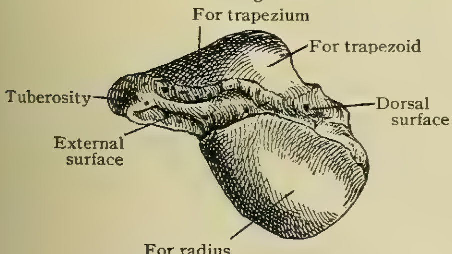
The hand is composed of the carpus or wrist, consisting of eight small bones arranged in two rows, which is succeeded by five rays of four segments each,—namely, a metacarpal bone and three phalanges, excepting the thumb, in which one phalanx is wanting.

THE CARPUS.

There are eight carpal bones arranged in two rows of four each. The first row includes, named from the radial towards the ulnar side, the *scaphoid*, the *semilunar*, the *cuneiform*, and the *pisiform;* the second row, the *trapezium*, the *trapezoid*, the *os magnum*, and the *unciform*. Exceptionally, several other bones may occur, due to the persistence of centres laid down in early fœtal life, which normally fuse with other centres or disappear. Thus there is much in favor of the view that the plan of the carpus is more complicated. This point is further considered in the discussion of variations (page 313). The pisiform of the first row, whatever may be its morphological significance, is in man practically nothing but a sesamoid bone in the tendon of the flexor carpi ulnaris, resting on the palmar surface of the cuneiform, and having no share in the mechanics of the wrist excepting as giving attachment to a part of the anterior annular ligament. The first row, therefore, consists really of the three first-mentioned bones, which are joined into one flexible piece by interosseous ligaments. The upper end of this combination bears an egg-shaped articular surface for the wrist-joint, to which all three bones contribute. Its lower side has a concavo-convex outline, the concavity receiving the inner two bones and the convexity bearing the outer two of the second row. The latter consists of four bones connected by ligaments: the trapezium, for the thumb; the trapezoid and os magnum, for the next two fingers; and the unciform, for the ring and little fingers. The dorsal side of the carpus is slightly convex and the palmar deeply concave, forming by its middle the floor of a deep canal, bridged by the anterior annular ligament, which runs between bony elevations on each side of the carpus. To shorten the description, it may be said that little depressions for ligaments can be seen on well-marked bones near their edges on the dorsal and palmar aspects, especially the former.

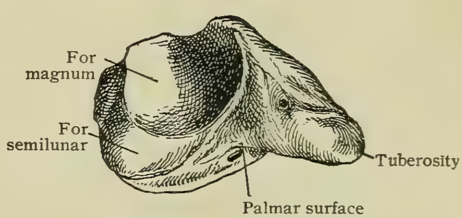
The **scaphoid** [os naviculare], or boat-shaped bone, is the largest and most external of the first row. It is a flattened elongated disk placed with the long axis running outward and downward. It receives its name from being convex on the upper and outer side for the radius and concave on the opposite side for the head the os magnum. Nearly corresponding with the long axis is the long and very

FIG. 321.



Right scaphoid, dorsal aspect.

FIG. 322.



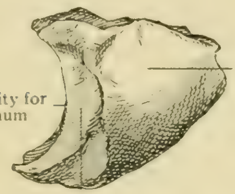
Right scaphoid, inner aspect.

narrow *dorsal surface.* The *palmar surface* is broader, runs more downward, and the outer end rises into the *tuberosity* of the scaphoid, from which part of the anterior annular ligament springs. The convex *proximal surface* for the radius is wholly articular; the inner edge is straight, the dorsal and palmar converge externally; it tends to encroach on the dorsal surface. *Internally* there are two surfaces, both

articular: the upper, very narrow, articulates at its lower border with the semilunar and gives attachment above to the fibro-cartilaginous ligament connecting these bones; the lower is an elongated cavity embracing part of the top and the outer side of the head of the os magnum. The *outer surface*, continuous with the dorsum, is a small groove for the lateral ligament of the wrist. The distal surface, forming the convexity of the medio-carpal joint, articulates with the trapezium and trapezoid. It is convex in all directions. The scaphoid articulates with *five* bones,—the radius, semilunar, trapezium, trapezoid, and os magnum.

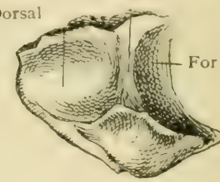
The **semilunar** [os lunatum] receives its name from its outline when seen from the side, the proximal surface being convex and the distal deeply concave. The *dorsal surface* is quadrilateral. Its proximal and inner borders are longer than the

FIG. 323.



Right semilunar, outer aspect.

FIG. 324.

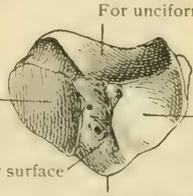


Right semilunar, inner aspect.

others, so as to make it kite-shaped, the long axis running distally outward. The two shorter surfaces meet at an overhanging point. The *palmar surface* is of the same general shape. Its larger distal portion is smooth as for a bursa. The *proximal surface* is convex and articular, chiefly for the radius; but, extending under the triangular cartilage, broadest at the scaphoid edge, it narrows internally. The concave *distal surface* is divided by a ridge into a larger part for the os magnum and an inner for the edge of the unciform. An *outer surface* articulates with the scaphoid and an *inner* with the cuneiform. Both are semilunar, but the outer is the more slender. Both are nearly plane and practically wholly articular, there being but a slight roughness for the interosseous ligaments at the proximal end near the dorsum. The semilunar articulates with *five* bones,—the radius, scaphoid, cuneiform, os magnum, and unciform.

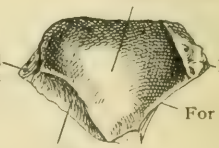
The **cuneiform** [os triquetrum], or *pyramidal*, is of such form that the latter name is the more fitting. The *base* is the articular surface for the semilunar; the *apex* is at the inner side of the wrist. The base is plane and articular except where the interosseous ligament joins it. The *dorsal surface* is narrow and not clearly

FIG. 325.



Right cuneiform, palmar aspect.

FIG. 326.



Right cuneiform, distal aspect.

separated from the proximal on the macerated bone. The *proximal surface* is a triangle with the base inward, and has near the base a smaller triangle of articular surface for the triangular cartilage. The inner half of the *palmar surface* is occupied by a round facet for the pisiform. The *distal surface* is a very complexly curved articular facet for the unciform. It suggests a saddle-joint that has been spirally twisted. A transverse section of this surface is concavo-convex from without inward.

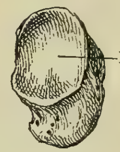
A vertical section near the outer end is concave, near the inner convex. It is practically a screw surface. A small part of the inner side is non-articular. The *inner surface* is the apex of the pyramid, a small knob for the lateral ligament. The cuneiform articulates with *three* bones,—the semilunar, pisiform, and unciform.

The **pisiform** [os pisiforme] is a small rounded bone, rough everywhere except where the greater part of one surface is occupied by a round, slightly concave articular facet which joins the palmar aspect of the cuneiform. The facet is at the proxi-

FIG. 327.

Right pisiform, dorsal aspect.

FIG. 328.

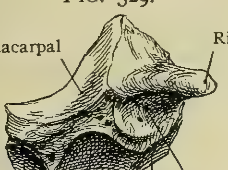


Right pisiform, palmar aspect.

mal part of the dorsal surface, the bone projecting from it downward, forward, and inward, lying in a plane anterior to that of the outer carpal bones. The pisiform articulates with only *one* bone,—the cuneiform.

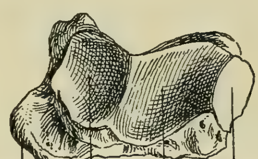
The **trapezium** [os multangulum majus] is distinguished by an isolated facet on the *distal surface* for the metacarpal bone of the thumb. This surface is that of a typical saddle-joint, concave from side to side where the borders are most raised ; convex from before backward ; broadest transversely. The *proximal surface* is a four-sided concavity for the scaphoid, separated by a ridge from the inner surface. The *inner surface* is subdivided : the proximal portion, much the larger, is an articular concavity for the trapezoid ; the distal portion is rough except for a facet at the dorsum for a part of the side of the second metacarpal. The *outer surface* is concave, receiving the lateral ligament. The *dorsal surface* is elongated from side to side, slightly hollowed in the middle, with a variously developed tubercle on

FIG. 329.



Right trapezium, palmar aspect.

FIG. 330.



Right trapezium, proximal and inner aspect.

either side. On the *palmar surface* is a deep groove for the tendon of the flexor carpi radialis. Just beside this is a prominent *ridge* at the junction with the external surface for a part of the outer insertion of the palmar annular ligament. The trapezium articulates with *four* bones,—the scaphoid, trapezoid, and first and second metacarpals.

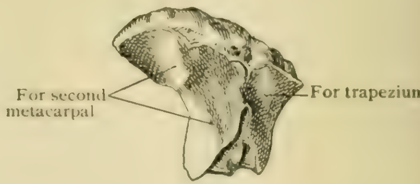
The **trapezoid** [os multangulum minus] is best recognized by the *dorsal surface*, which is pointed distally where it projects into the second metacarpal. The outer convex border against the trapezium is much longer than the inner against the os magnum. The *proximal border* runs obliquely forward and inward. The small *palmar surface* is irregularly quadrilateral. The *proximal surface* is a quadrilateral, nearly plane, facet for the scaphoid, longer from dorsum to palm than transversely. The *distal surface*, entering the base of the second metacarpal, is divided by a ridge into two facets, concave from dorsum to palm, of which the inner is the longer. The *internal surface*, in the main concave, articulates with the body of the os magnum, but has a non-articular surface near the dorsum for an interosseous ligament. The *outer surface* is mostly articular and slightly convex, joining the trapezium ;

distally and towards the palm there is a rough surface for ligaments. The styloid process of the third metacarpal often reaches the dorsal aspect of the trapezoid

FIG. 331.

Right trapezoid, inner aspect.

FIG. 332.

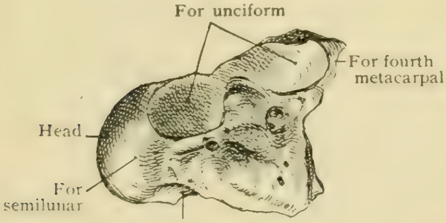


Right trapezoid, outer and distal aspect.

between the os magnum and the second metacarpal. The trapezoid articulates with *four* bones,—the scaphoid, trapezium, os magnum, and second metacarpal.

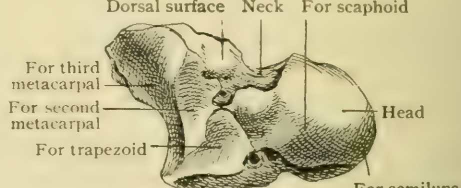
The **os magnum** [os capitatum] is the largest bone of the carpus, and possesses a head, neck, and body. The *head* is a rounded articular eminence at the proximal end, playing in a socket formed by the scaphoid, semilunar, and unciform. The convex articular surface extends much farther on the dorsal side than on the palmar. A faint line above often separates the part resting on the scaphoid from that resting on the semilunar. The former extends down the outer side of the head. The inner side of the head is a sharply cut plane surface articulating with the unciform. The *neck* is a constriction, best marked on the dorsal aspect, generally seen on all sides except the inner. The *distal surface*, broader on the dorsal end, faces a little outward. It is wholly articular, bearing the third metatarsal bone. A groove in the place of the outer angle receives the edge of the second metatarsal. A smaller surface for the fourth exists at the inner angle just below the dorsum. The *dorsal*

FIG. 333.



Right os magnum, inner aspect.

FIG. 334.



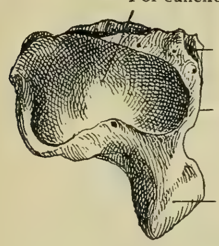
Right os magnum, outer aspect.

surface shows the head, and distally to it a sharp, slightly concave inner border, a shorter outer one, and a distal one slanting downward and inward, so that the outer angle is obtuse and the inner would be acute, but that the point of the angle is replaced by a small border touching the fourth metacarpal. The *palmar surface* is narrow and prominent below the neck. The *inner surface* is rough for a ligament near the palmar border; above, it has a narrow articular surface for the unciform, continuous with that on the head. The *outer surface* has a small articulation with the trapezoid, which exceptionally is continuous with the facet on the head. The os magnum articulates with *seven* bones,—the scaphoid, semilunar, trapezoid, unciform, and second, third, and fourth metacarpals.

The **unciform** [os hamatum] is distinguished by a prominent hook projecting from the inner side of the palmar surface for a part of the annular ligament. The *dorsal surface* is nearly or quite triangular. It presents an oblique proximal border, a nearly straight, but often convex, outer one, and a distal one tending to meet the inner end of the proximal border. Should they meet, the surface is triangular; but more often there is a very short inner border separating them, which is either straight

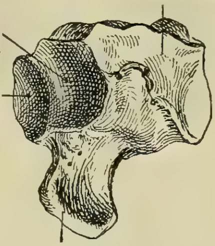
or concave. The *palmar surface*, of about the same shape as the dorsal, presents externally a deep groove, a part of the canal for the flexor tendons, overhung internally by the *unciform process*, which has a broad outer and inner surface, the former concave and smooth, the latter convex. The free border of the hook presents a curved outline from the inner side. The rounded edge between the proximal and outer surfaces rests against the semilunar. The *proximal surface* is a spirally twisted, oblong facet corresponding to the adjacent side of the cuneiform, with a prominent convexity at the proximal end. The *outer surface*, rough at the distal and palmar angles for an interosseous ligament, is elsewhere articular for the os

FIG. 335.



Right unciform, inner and proximal aspect.

FIG. 336.



Right unciform, outer and distal aspect.

magnum. The *distal surface*, wholly articular, bears the fourth and fifth metacarpals, a ridge marking the interspace between them. The surface is, in the main, convex from side to side and concave from dorsum to palm. Often, however, the part for the fourth finger is concave from side to side and convex in the other direction. The distal surface may meet the proximal at a sharp border, or a very narrow rough surface may intervene. The unciform articulates with *five* bones,—the semilunar, cuneiform, os magnum, and fourth and fifth metacarpals.

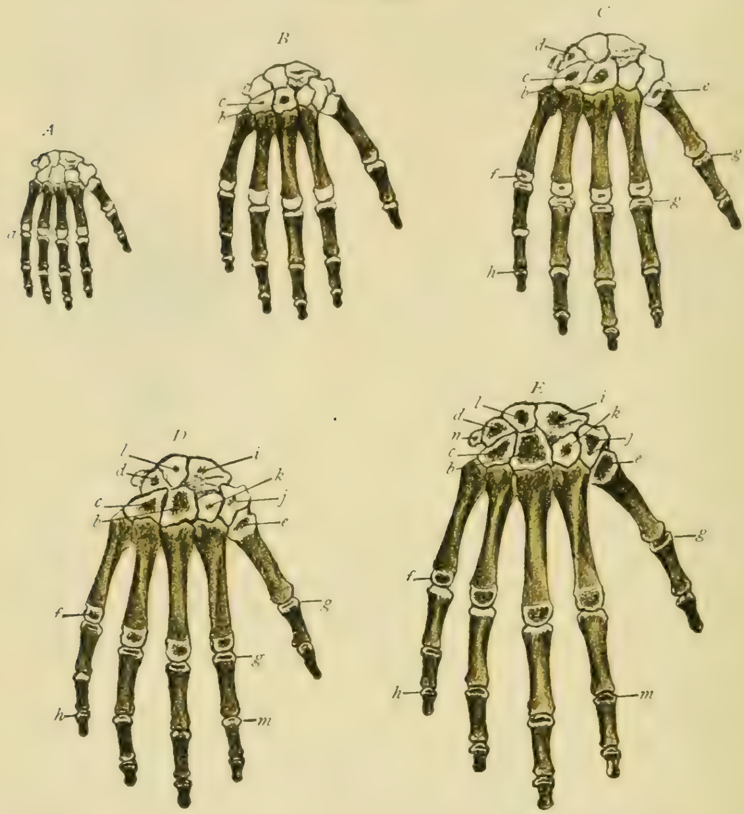
Development and Variations.—In early fœtal life centres appear for the above-described carpal bones, and also for many others, which disappear, or are fused with the usual ones, long before the appearance of bone. Additional carpals depend either on the persistence and subsequent ossification of centres that normally are lost or on the separate development of two or more that should fuse. The number of carpal elements is put by Pfitzner[1] at thirty-three. He arranges the constant and possible bones in five rows: (1) an *antibrachial row*, consisting of an ossification in or on the triangular cartilage, representing the *os intermedium*, and a little apparent outgrowth from the pisiform; (2) a *proximal row*, consisting of the normal bones and certain subdivisions of the scaphoid and cuneiform; (3) a *central row*, composed entirely of occasional bones; (4) a *distal row*, composed of the four normal bones plus a minute *metastyloid;* (5) a *carpo-metacarpal row*, composed entirely of occasional bones. The most common anomaly is the appearance of a *styloid bone*, which is the separated styloid process of the third metacarpal. The *metastyloid* of the fourth row is a minute bone representing the very tip of the styloid. Very rarely the scaphoid is divided into a radial and an ulnar part. The *os centrale* is the persistence of still another piece, which normally either joins the scaphoid in the third month of fœtal life or disappears. It apparently is composed of a dorsal and a palmar element, of which the latter is the more subject to degeneration. The os magnum contains two elements exceedingly rarely found distinct, the *subcapitatum* on the distal end of the palmar surface and the *subcapitatum secundarium* forming the inner distal angle of the dorsum. The hook of the unciform may be separate. Fusion may occur between bones normally distinct. The semilunar may fuse with the cuneiform, especially in negroes.

Ossification occurs from one centre for each bone; but according to some authorities, the unciform and the scaphoid have two centres. The former and the os

[1] Zeitschrift für Morphologie und Anthropol., Bd. ii., 1900.

magnum are the first to ossify, the process beginning in the latter part of the first year. The order of its appearance in the other bones is very uncertain. Those of the first row, excepting the pisiform, contain bone by the end of the first five or six

FIG. 337.



Ossification of bones of hand. *A*, at birth; *B*, latter half of first year; *C*, at three years; *D*, at eight years; *E*, at twelve years. *a*, centres for shafts of metacarpals and phalanges; *b*, magnum; *c*, unciform; *d*, cuneiform; *e*, base of first metacarpal; *f*, heads of metacarpals; *g*, bases of proximal phalanges; *h*, bases of distal phalanges; *i*, scaphoid; *j*, trapezium; *k*, trapezoid; *l*, semilunar; *m*, bases of middle phalanges; *n*, pisiform.

years. These are followed by the trapezium and the trapezoid, so that by the eighth year the process has begun in all the carpals save the pisiform, in which it begins about the twelfth year.

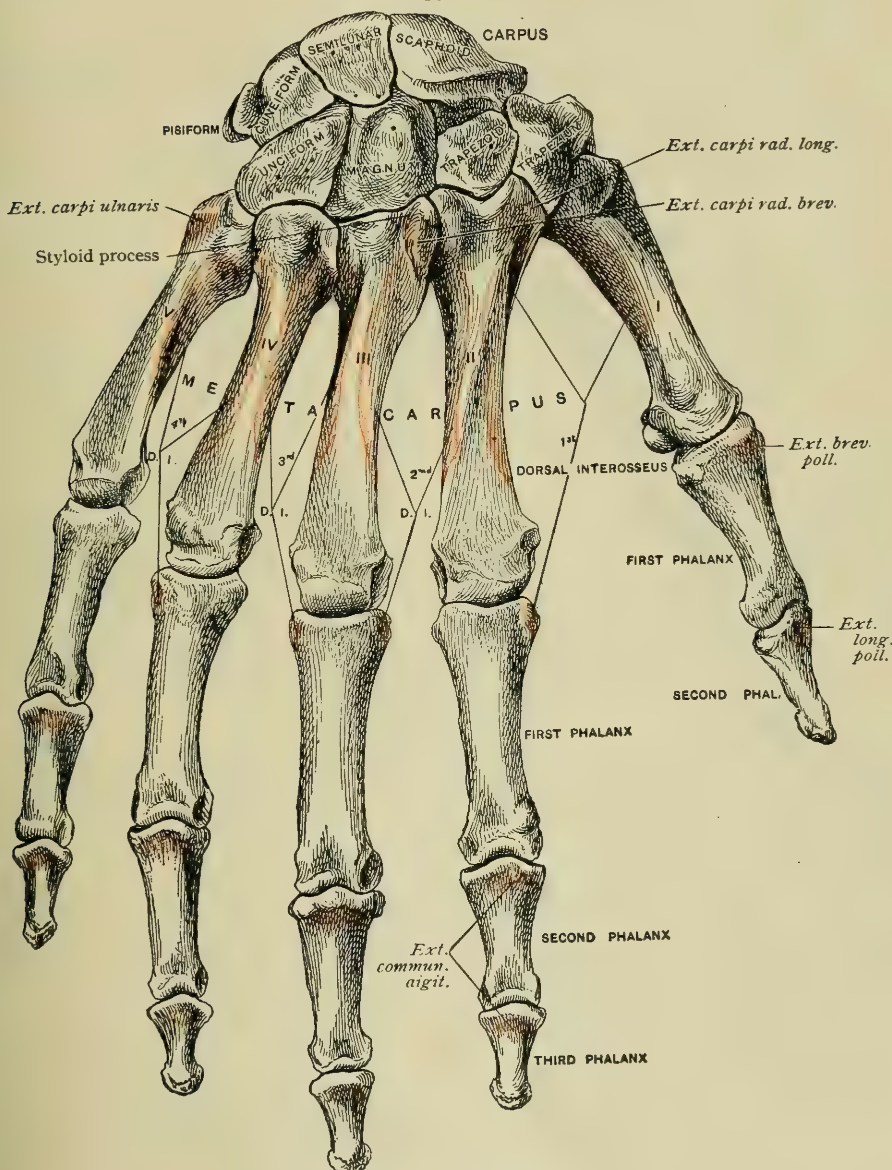
THE METACARPAL BONES.

The metacarpal bone of the thumb[1] in many respects resembles a phalanx and calls for a separate description; the others have the following points in common. They possess a shaft[2] and two extremities, of which the proximal is the *base* and the distal the *head*.[3] Each *base*[4] has an articular surface at the end to join the carpus and one on the side or sides that come into contact with the other metacarpal bones, with a depression for an interosseous ligament beyond it. The bases themselves are cubical and rough both above and below. The *shaft* narrows in front of the base, and has a *median dorsal ridge*, which soon divides into two lines running to either side of the head, thus bounding a long, flat dorsal surface occupying more than half the bone. A *palmar ridge* runs nearly the whole length of the shaft, dividing very near the head into two faint lines to either side of it. Thus, near the base the shaft may be called cylindrical, with a ridge above and below, while farther forward it has a dorsal and two lateral sides. This description applies most closely to the bone of the index, and becomes less and less accurate as we proceed to the little

[1] Os metacarpale I. [2] Corpus. [3] Capitulum. [4] Basis.

finger. The *distal end* or *head* has a rounded articular surface projecting to the palmar side, while it does not rise above the level of the dorsum. Both on the palmar and dorsal aspects, but especially on the former, its angles are produced backward, and the whole surface encroaches a little more on the palmar side, where it is decidedly broader than on the back. A *tubercle* exists on each side where the diverging

FIG. 338.



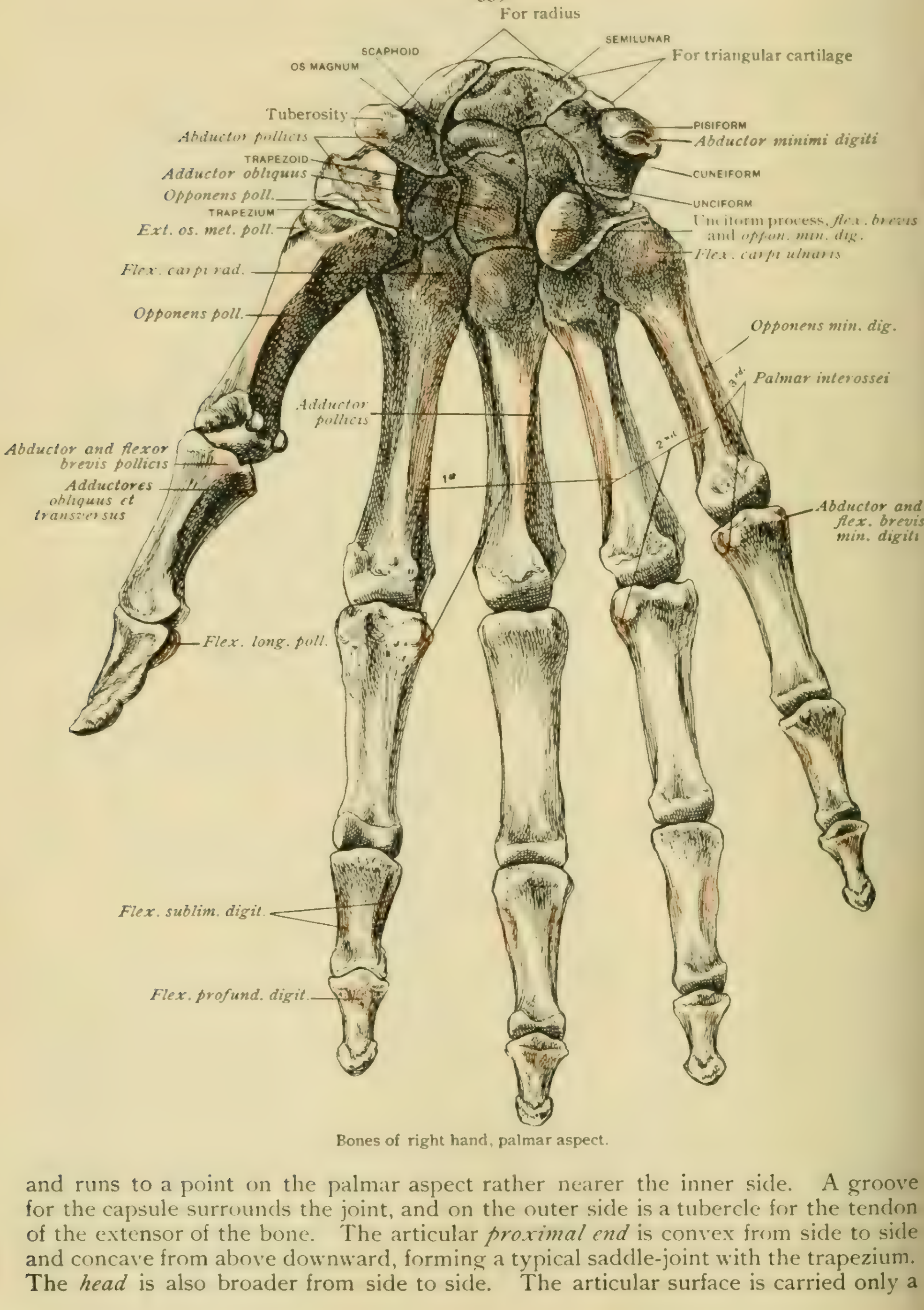
Bones of right hand, dorsal aspect.

lines of the dorsum end, with a depression below it on the side of the head. The lateral ligaments spring from both tubercle and depression. The *nutrient foramina*, excepting that of the first metatarsal, are recurrent, running towards the proximal end.

Peculiarities of the Different Metacarpals.—The first metacarpal is shortest, the second longest, from which the remaining ones decrease in length from without inward. The chief distinguishing marks are on the bases.

The **first metacarpal**, shorter than the others, has a nearly flat *dorsal surface* bounded by two definite borders, of which the outer is the sharper. The *palmar surface* of the shaft is overhung by the ends. It is thickest and most convex towards the inner side. These two points are the best guides to determine the side the bone belongs to. The difference is striking in a transverse section. The *base* is broad

FIG. 339.



Bones of right hand, palmar aspect.

and runs to a point on the palmar aspect rather nearer the inner side. A groove for the capsule surrounds the joint, and on the outer side is a tubercle for the tendon of the extensor of the bone. The articular *proximal end* is convex from side to side and concave from above downward, forming a typical saddle-joint with the trapezium. The *head* is also broader from side to side. The articular surface is carried only a

little way onto the dorsum, but bends strongly forward, ending in two lateral prolongations with a notch between them, on each of which a sesamoid bone plays. The outer of these is the more prominent. The *nutrient foramen* runs towards the distal end.

The **second metacarpal** has a base which is triangular when seen from the end, and forked to straddle the point of the trapezoid. On the outer side is a small square facet near the dorsum for the trapezium ; on the inner side there is a narrow oblique surface for the os magnum, and in front of it one showing a tendency to subdivide, articulating with the next bone.

The **third metacarpal** has an oblong proximal surface, broadest on the dorsum, where a tubercle, the *styloid process*, projects towards the trapezoid. We have found the third metacarpal touching this bone in forty per cent. of 100 specimens, and sometimes this occurred when the styloid process was not particularly developed. Externally there is a facet like the lower part of the inner one of the second, and internally a double one to meet the next.

The **fourth metacarpal** has a nearly square upper surface articulating with the unciform, and therefore of uncertain nature,—sometimes convex, sometimes concave. At the outer dorsal angle of this surface is a small distinct facet for a joint with the os magnum. On the outer side are two facets for the third, and on the inner a long one, concave from dorsum to palm, for the fifth.

The **fifth metacarpal** has a base generally broader than deep, concave from side to side and convex from above downward. A single facet on the outer side has a convexity to meet the concavity on the fourth. The inner side has, of course, no facet, but a tubercle. The dorsal ridge on this bone is twisted, starting from the inner side.

Development.—Each bone has two centres, a primary one for the shaft, appearing early in the third month of fœtal life, and one for an end, appearing in the third year. The secondary centre is for the distal end in the four inner metacarpals and in the proximal of the first,—that is, at the end towards which the nutrient artery does not run. They fuse at about eighteen. Rarely smaller epiphyses appear at the other ends also, as in mammals generally. A centre for the styloid process of the third is sometimes seen, and it may become distinct, as an extra carpal bone, or it may fuse with one of the adjoining ones.

THE PHALANGES.

Features of Each Bone.—The phalanges[1] of the first and second row differ (except in size) only in the proximal ends. The dorsum of the *shaft* is rounded from side to side ; the *palmar surface* is flat with raised edges for the sheaths which bind down the tendons very closely. It is considerably overhung by the distal and somewhat by the proximal end. The *nutrient foramen*, when present, runs distally.

The *proximal end* of the *first row* is a concave articular surface, broadest transversely. A groove runs round the end, except on the palmar surface, for the capsule and for fibres from the extensor tendons of the fingers on the dorsum. Two very slight inequalities in front mark the attachment of the glenoid ligament. There is a rough tubercle on each side, just below the groove for the partial insertion of the interosseous muscles. The *distal end* in both the first and second rows has an articular surface which curves over two *condylar prominences*, separated by a median furrow, onto the palmar aspect. This surface is seen on the dorsum only as a small curved median facet which broadens as it passes over the end and continues to expand to its termination. The lateral borders of the joint are well defined. A depression with an overhanging tubercle is on each side of this end ; both depression and tubercle give attachment to the lateral ligament.

The *proximal ends* of the *second* and *third rows* are essentially the same. They differ from that of the first row because, while the latter fits onto the single rounded end of a metacarpal, those of the two distal rows fit onto double condylar ends. Thus the proximal articular surface presents a median elevation, separating two hollows, continued into a projecting point on the surface front and back. In the phalanges of the second row the dorsal point is the larger ; in the last row the points

[1] Phalanges digitorum manus.

are about equal. In the last row the palmar point is at a lower level than the roughness that succeeds it. There is a transverse ridge in both on the dorsal aspect for extensor tendons; the flexor tendons are inserted on the palmar side to a slight ridge on the second phalanx and to a roughness spreading considerably on the shaft of the terminal one.

The *phalanges* of the *third row* are much smaller and flatter than the preceding. The dorsum of the diminutive shaft is convex from side to side and its palmar aspect plane where not encroached upon by roughnesses. The free end is sharp and rounded, with points at each end projecting backward. The dorsal distal border bears a narrow semilunar roughness; a much broader one on the palmar side supports the pulp of the end of the finger, giving firm attachment to the connective tissue.

Peculiarities of Individual Phalanges.—Every phalanx of the first row is longer than any of the second row. The first and second phalanges of the middle finger are longer than the corresponding ones of the ring finger, which in turn surpass those of the index. Those of the little finger are the smallest. The terminal phalanges are of very nearly the same length.

The **phalanges of the first row** have the following peculiarities. That of the *index-finger* has a very large external tubercle at the dorsum; the hollow at the base is deeper than that of any other; the base is relatively strong compared with the shaft, which is flatter than any other. The phalanx of the *middle finger* is strong in all its parts; there is a large external tubercle, often divided into a dorsal and a palmar part; at the distal end the ulnar condyle is more prominent. The phalanx of the *ring finger* has the base relatively small and the condyles relatively large, so that the borders are nearly parallel; the dorsum is more convex transversely than that of the third, and much more so than that of the index; it is also narrower. The phalanx of the *little finger* is weak, narrowing rapidly so as to appear pointed; there is a tubercle at the inner and dorsal side of the base, and the radial condyle is the more projecting. One cannot, therefore, determine to which side the phalanx of the ring finger belongs.

In the **second row** the phalanx of the middle finger is always stronger than that of the ring finger, and the latter than that of the index. According to Pfitzner,[1] the distal ends are the more characteristic. In the second finger the radial condyle is the more prominent; this is also true in the third, but to a less degree; the ulnar condyle is the larger in the fourth, and still more so in the fifth.

The **distal** or **terminal phalanges** can be distinguished more surely by strength than by length; the third is the strongest; then comes the fourth; next the second, which is more or less pointed; and last the fifth, which is relatively weak. These characteristics are to be used with great caution in drawing differential deductions.

Development.—The phalanges have each a centre for the shaft and one for the proximal end. The former appears in the latter half of the third month of fœtal life at about the same time in the terminal and proximal rows. Probably the terminal row shows ossification somewhat earlier than the other (Bade). The centres for the second phalanges appear after a distinct interval about the middle of the fourth month. In both the first and second rows the centre appears nearer the proximal end. It is said that in all the rows ossification begins in the middle finger, next in the index, and later in the ring and little fingers; there is, however, considerable variation. The centre for the second phalanx of the little finger is distinctly later than the others. Ossification begins in the epiphyses in the third year or later. They are fused by eighteen. In addition to the proximal epiphyses, the terminal phalanges have each a distal cap-like ossification of perichondrial origin, which quickly joins the shaft.

Sesamoid bones[2] occur in the metacarpo-phalangeal joints. In the fœtus of the fourth month they are very numerous, but many disappear by fusion or otherwise during development. A pair is constant in the joint of the thumb. They are two bones of variable size, in general rather larger than a small pea, lying on the palmar side of the head of the first metacarpal. The tendon of the long flexor passes.

[1] Schwalbe's Morpholog. Arbeiten, Bd. i. and ii., 1893.

[2] Ossa sesamoidea.

between them. They each have one cartilage-covered surface against the bone and are otherwise surrounded by fibrous tissue. A small one on the radial side of the joint of the index-finger occurs in rather less than half the cases, and one on the ulnar side of the little finger in rather more than four-fifths. Pfitzner[1] gives the following table of percentages showing the frequency of the various sesamoid bones, combining his work and that of Thilenius :

	Number of Hands.	Thumb.		Index.		Middle.		Ring.		Little.	
		Rad.	Uln.	R.	L.	R.	L.	R.	L.	Rad.	Uln.
Fourth-month fœtus . .	30	100	100	46	23	30	15	23	30	15	63
Fourteen to ninety years	1323	99.9	100	47.8	0.1	1.5	0	0	0.1	2.3	82.4

Variations in the number of the fingers are generally regarded as malformations. The most common occurrence is an extra finger, the identification of which is not certain. It seems often as if we should content ourselves with saying that there is an extra finger, but that no particular one has been repeated. Sometimes the thumb has three phalanges. Occasionally any of the terminal phalanges is doubled. A very uncommon condition is that of seven or eight fingers and no thumb. The dissection of such a case revealed the absence of the radius and of the radial side of the wrist, the skeleton of the forearm consisting of two ulnæ, and that of the hand of the ulnar sides of two opposite ones fused together.

PRACTICAL CONSIDERATIONS.

The Carpus.—Of the carpal bones the scaphoid and semilunar are most frequently broken, on account of their more direct relation to the line of transmission of force in falls upon the hand. The diagnosis is difficult, and has been made oftenest by the help of a skiagraph. There is but little displacement. The other bones of the carpus, on account of their shortness, irregular and rounded shape, and compact union by strong ligaments which yet permit slight movements between the bones, usually escape injury except in cases of crush of the whole hand. They are, however, not infrequently the seat of tuberculous disease, as might be expected from their great liability to traumatism of all grades. Their synovial relations (Fig. 342) favor the spread of such disease from one bone to the remainder, and render conservative treatment unsatisfactory. The result, too, is affected by the close proximity of the flexor and extensor tendons, which become involved in the tuberculous process or bound down by adhesions.

The Metacarpus.—The first metacarpal bone, which is morphologically a phalanx, is, like all the phalanges, developed from an epiphysis situated at its proximal end. But one case of disjunction has been recognized during life. It resembled a dislocation at the carpo-metacarpal joint, but the seat of abnormal movement was below the level of the lower edge of the trapezium. In the remaining metacarpal bones the epiphysis is situated at the distal extremity.

Falls upon or striking with the closed fist tend to produce forward displacement. As the metacarpal bones of the index-, middle, and ring fingers are the longer, their epiphyses are more likely to be separated in this manner. A fall on the extended fingers and metacarpo-phalangeal region may cause backward displacement, though this is rarer.

The diagnosis from dislocation of the proximal phalanges is not easy. It is aided by the recognition of "muffled crepitus" (Poland) and by the great tendency of the deformity to recur, due partly to the small articular areas of the separated bones and partly to the action of the flexors and the interossei. Skiagraphy will usually establish the diagnosis.

Fracture of the metacarpal bones is usually the result of a blow with the clenched fist. The metacarpals of the thumb and little finger are therefore rarely broken. On account of the mode of application of the force, the seat of fracture is

[1] Zeitschrift für Morph. und Anthropol., Bd. ii., 1901.

apt to be near the distal end, although the thinnest and weakest parts of the bones are just above the middle and they sometimes break there. The proximal fragment is held firmly by its ligamentous attachments and is less movable than the phalangeal portion ; its distal end may project on the dorsum. The knuckle of the affected finger sinks and partially disappears. The lumbricales and the interossei aid in producing this deformity, and may cause the proximal end of the distal fragment to become prominent on the dorsum of the hand. In examining for these fractures it should be remembered that the metacarpal bones of the index- and middle fingers are bound tightly to the carpus and possess but little power of independent movement. The others are more movable. In the treatment of these fractures the normal palmar concavity of the metacarpal bones should never be forgotten.

The Phalanges.—Epiphyseal separation of the phalanges is extremely rare. The epiphyses are all at the upper ends of the bones. The diagnosis from severe sprain or from fracture will usually be made by the X-rays. It is now thought that not a few of the cases of necrosis of the proximal end of a phalanx following acute inflammation or whitlow are the result of epiphyseal sprain or disjunction. Of course, necrosis is often the sequel of the spread of infection from the superficial structures of the hand to the closely applied fibro-cellular tissue over the terminal phalanges.

Fractures occur most frequently in the proximal and most rarely in the terminal phalanges. The relation of the tendons on the dorsal and palmar surfaces usually prevents any marked displacement. Occasionally an anterior angular deformity of the proximal phalanx is seen after fracture. It is believed to be favored by the action of the interossei.

The frequency with which both tuberculous and syphilitic inflammations affect the phalanges is probably due to their exposure to slight injury. They are, however, not often the subject of post-typhoidal infection. The cause of whitlow has already been mentioned, and will be recurred to. The reason for the overgrowth of the bony structures of the hand in acromegaly and in hypertrophic pulmonary osteo-arthropathy is not known. In the latter case it has been suggested that the enlargement of the terminal phalanges, like the "clubbing" of the fingers in phthisical patients, may be due to an osteogenetic stimulus derived from the presence in the circulation of the secondary products of the pulmonary infection. This would be analogous to the increased rapidity of growth observed in adolescents during convalescence from typhoid.

Landmarks.—On the inner side of the hand, below the wrist, the pisiform bone can be felt, and when grasped firmly can be given slight lateral movement. Lower and more externally the hook of the unciform can be made out. On the outer side the tuberosity of the scaphoid just below and internal to the radial styloid and still lower the ridge of the trapezium may both be felt. With the hand in full flexion, the dorsal prominence of the scaphoid and semilunar and the curved line of their articulation with the radius may be felt ; the anterior and posterior lips of the articular surface of the latter bone can be palpated and the groove or depression beneath them recognized. The projection of the os magnum on the back of the hand, and occasionally of the base of the third metacarpal at its articulation with the os magnum, may easily be felt. When an unusual prominence of these bones exists, and is first noticed after a fall or strain, it sometimes leads to a mistaken diagnosis of exostosis or of ganglion.

The metacarpal bones, their concavity, their expanded anterior extremities forming the knuckles, the shape and size of the shafts and ends of the phalanges, and of their articulations with the metacarpus and with each other, can all readily be made out through or between the overlying tendons.

The surface markings of the hand and of its joints will be considered later (page 621.)

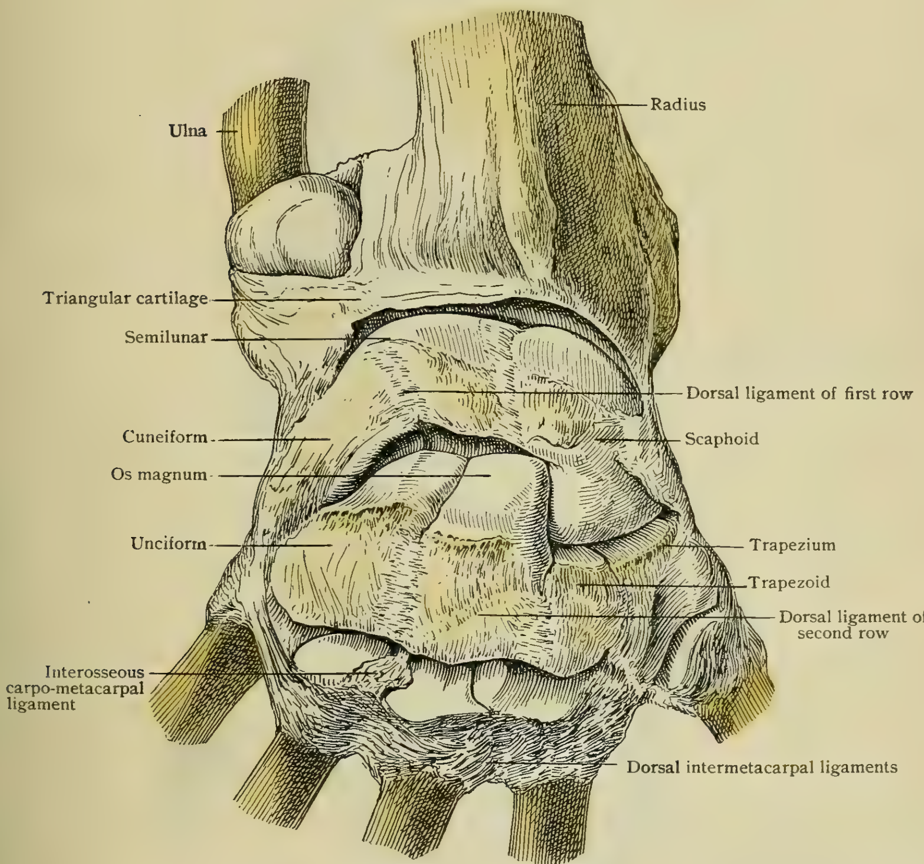
LIGAMENTS OF THE WRIST AND METACARPUS.

The ligaments and joints of the wrist include three articulations, the *radio-carpal*, the *intracarpal*, and the *carpo-metacarpal*, which often receive detailed separate description. The simpler and in many ways more desirable conception of these joints is to regard them as parts of a common articulation consisting of a

general capsular ligament enclosing synovial cavities separated by an interarticular fibro-osseous septum composed of the bones of the first row and their interosseous ligaments. Preparatory to the common description which follows, it is necessary to consider the ligaments and relations of the groups of bones which take part in the formation of the subdivisions of the general articulation.

The pisiform being practically a sesamoid bone, the upper end of the carpus is an egg-shaped articular surface made chiefly by the convexities of the scaphoid and semilunar and to a small extent by the cuneiform (Fig. 340). These three bones are united into one apparatus by two strong *interosseous ligaments* situated just below the proximal ends of the bones, covered by synovial membrane and com-

FIG. 340.



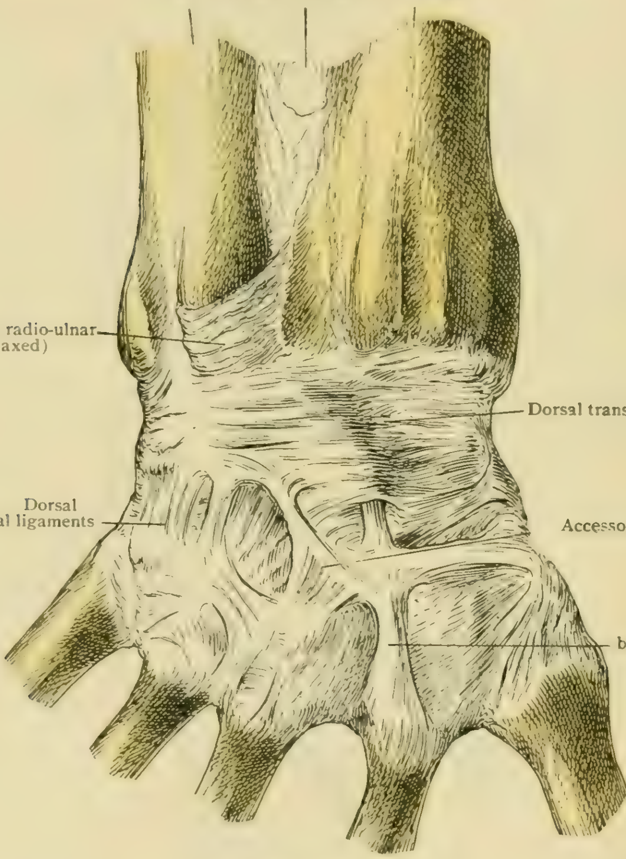
Dorsal aspect of right wrist. The joint of ulna is opened and the shaft displaced forward and inward to show under side of head. The radio-carpal, intracarpal, and carpo-metacarpal joints are shown by removing the dorsal ligaments and flexing the hand.

pleting the articular surface. They completely shut off the radio-carpal from the intracarpal joint. The latter is concavo-convex, the *concave part* being formed by the cuneiform, the semilunar, and the hollow surface of the scaphoid ; the *convexity* by the lower surface of the latter bone, which articulates with the trapezium and trapezoid. The concavity amounts to a socket, of which the side formed by the scaphoid is nearly at right angles to the base, while the inner, formed by the cuneiform, is oblique. The scaphoid is attached to the semilunar much less tightly than is the cuneiform, so that considerable motion occurs between them. The scaphoid, besides sliding in various directions on the semilunar, can turn on an approximately transverse axis through its proximal part, which permits of flexion and extension, to some degree independent of the rest of the first row. Its lower end may also move

somewhat outward and inward, so as to broaden or narrow the socket. The distal row of carpal bones presents a prominence made by the os magnum and the unciform, which are held firmly together so as to move nearly as one, fitting into the socket presented by the first row. The outer side of this prominence is quite straight, making an entering angle with the trapezoid, receiving the ridge between the concavity and convexity of the scaphoid. At this point near the palmar surface the os magnum receives a ligament from the scaphoid, which may occasionally deserve to be called interosseous. The pisiform has a capsular ligament enclosing the joint between it and the cuneiform.

The four bones of the second row are joined by three *interosseous ligaments:* one

FIG. 341.

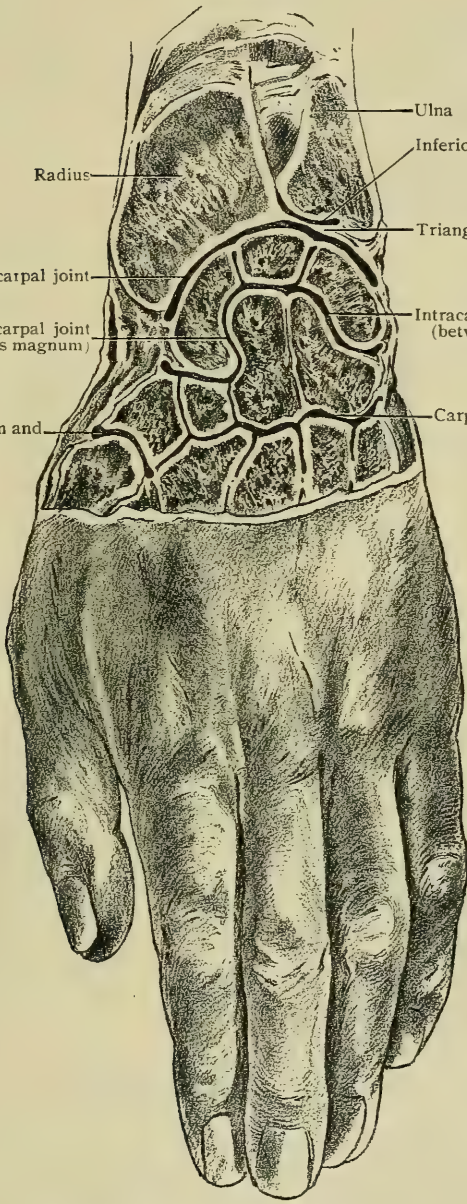


Dorsal aspect of right wrist.

between the trapezium and trapezoid, near the palm ; one between the trapezoid and os magnum, near the dorsum ; and one between the os magnum and unciform, much the strongest, connecting the palmar halves of the bones at the distal end. None of these interrupt the communication of the synovial cavity of the intracarpal joint and those at the bases of the metacarpals. The scaphoid, semilunar, and cuneiform have very properly been compared to an intra-articular fibro-cartilage or *meniscus*, subdividing a joint. No muscle of the forearm is inserted into them. (The flexor carpi ulnaris, which has the pisiform as a sesamoid bone in its tendon, has its real termination in the fifth metacarpal.) Hence this series is never directly moved, but changes position under the pressure of the distal row, which is pulled against it by the muscles moving it. It plays an important part in the movements of the joint.

The bases of the metacarpals, except the thumb, articulate with one another by the lateral facets, and just below these joints are held together by strong interosseous ligaments connecting the rough depressions below the bases. The fibres of the

FIG. 342.



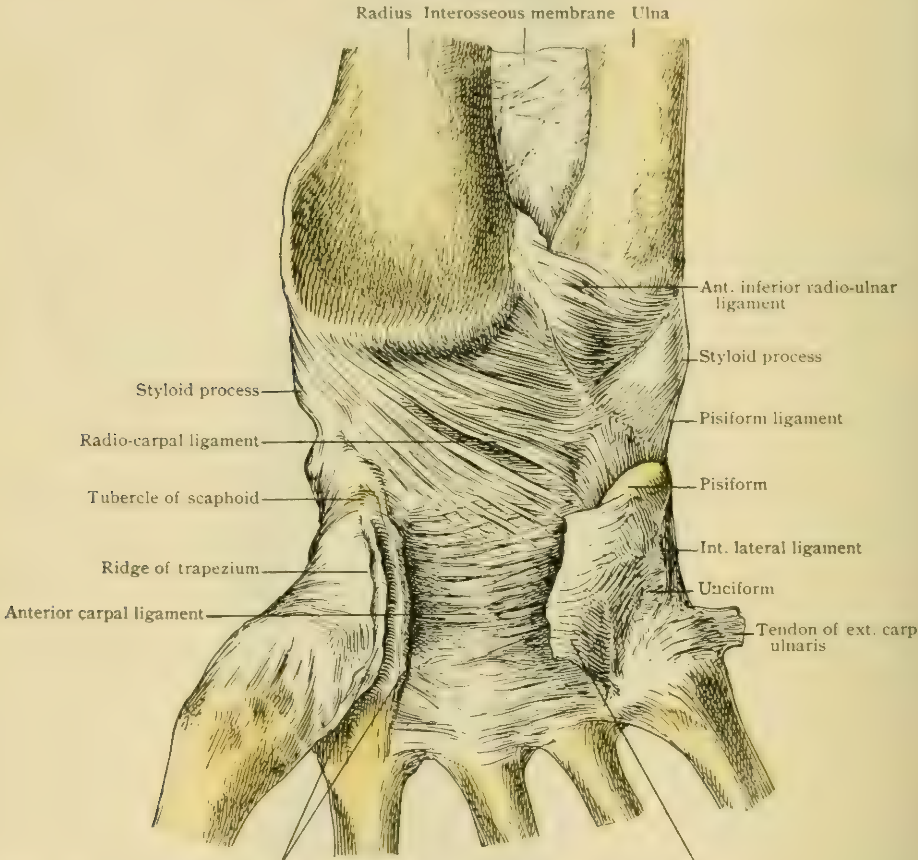
Carpal synovial sacs seen in longitudinal section.

interosseous ligament from the trapezium to the trapezoid are inseparable from some from the trapezium to the second metatarsal.

A common description will best serve for the ligaments connecting the forearm, the first row, the second row, and the bases of the metacarpals (Figs. 340, 341). The simplest conception is of a **capsule** passing from the forearm to the metacarpus and attached to the intervening bones. It is much strengthened by neighboring

tendons and their sheaths. It is strong at the sides; weak in front and behind. The stronger bands are inextricably blended with the rest; that on the outside, the *external lateral ligament*,[1] runs from the radial styloid process to the outer side of the scaphoid, thence to the trapezium, and is continuous with the capsule of the carpo-metacarpal joint of the thumb. The *internal lateral ligament*[2] runs from the styloid process of the ulna to the side of the cuneiform, and to the pisiform, thence to the narrow internal edge of the unciform, and finally to the fifth metacarpal. The *dorsal part* of the capsule is the weakest, but is much strengthened by the extensor tendons. A continuous layer passes from the radius and ulna to the first row, thence to the second, and thence to the metacarpals. The general direction of the fibres of

FIG. 343.



Anterior aspect of right wrist-joint. A portion of the anterior annular ligament has been removed and the canal for the flexor carpi radialis opened.

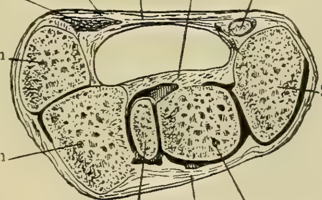
the proximal part is transverse, inclining inward from the styloid process of the radius and the scaphoid to the cuneiform. This constitutes the *dorsal transverse ligament*, which serves to hold the head of the os magnum and the adjoining part of the unciform in the socket made by the concavity of the first row. It has no definite borders. Tolerably distinct bands pass to the bases of the four inner metacarpals; those to the second and third are tense and the others lax. Various accessory bands are often found. The *anterior part* of the capsule in the hollow of the wrist is stronger: it is reinforced by oblique bands converging downward. Many of these fibres are attached to the narrow palmar prominence of the os magnum. Pretty distinct bundles go to the bases of the metacarpals. Very small disks project into both the radio-carpal and the intracarpal joints from the dorsum, which are hardly seen except

[1] Lig. collaterale carpi radiale. [2] Lig. collaterale carpi ulnare.

in frozen sections. Their broader bases are attached to the capsule, and the free sharp edges end in the joint fitting in between the bones.

The *pisiform* has a special joint on the palmar side of the cuneiform, with a lax capsule. This is strengthened internally by a bundle from the cuneiform running from the dorsal to the palmar side. Two well-marked bands pass downward from it on the latter aspect; the one to the base of the fifth metacarpal is really the end tendon of the flexor carpi ulnaris, the other passes obliquely to the proximal edge of the unciform process.

FIG. 344.



Transverse section through right wrist from above. The flexor tendons have been removed from the canal beneath the annular ligament.

The Anterior Annular Ligament.—This is an extremely strong structure, bridging the hollow of the wrist, and enclosing a canal through which pass the tendons of the long flexors of the thumb and fingers and the median nerve. It springs internally from the process of the unciform and from the pisiform, the latter part being fused with the band from it to the unciform. It is attached externally to the ridge on the trapezium, and by a deeper process to the tuberosity of the scaphoid and to the inner side of the front surface of the trapezium, thus splitting to allow the passage of the tendon of the flexor carpi radialis through a special canal in the groove of the trapezium. Frozen sections through the wrist, passing through the pisiform (Fig. 344) (but not those through the unciform), show deep fibres from the annular ligament passing down under the canal and blending with the front of the capsular ligament of the wrist. The proximal and distal borders of the ligament are somewhat artificial, as it is connected with the fascia of the forearm and with the palmar fascia, besides receiving fibres from the flexor carpi ulnaris. This anterior annular ligament holds the sides of the wrist firmly together and prevents them from spreading when pressure is applied from above. Its fibres mingle with the origins of muscles of the thumb and of the little finger.

FIG. 345.

Frozen section through right middle finger, the hand being straight.

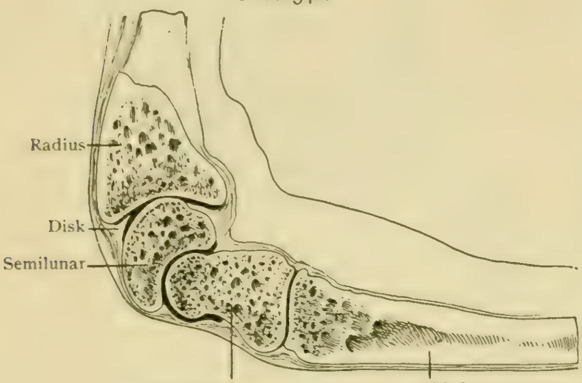
The **posterior annular ligament** is but a thickening of the fascia of the back of the forearm, and has no place among the true ligaments.

The Carpo-Metacarpal Articulations.—Those of the four inner fingers have been partially described. They connect with the general articular cavity of the wrist. A band from the adjacent edges of the os magnum and unciform to those of the third and fourth metacarpals (Fig. 340) does not completely interrupt the continuity of this cavity, as it does not reach the dorsal surface. The carpus and metacarpus are connected on both front and back by bands which can be fairly distinguished from the capsule. Transverse bands run also on both surfaces from the base of one metacarpal to the next. The opposed sides of the bases are partly covered with articular cartilage,

as has been described. *Interosseous metacarpal ligaments* connect their sides distally from this. These complete the capsules, which are imperfect only on the carpal side.

The **articulation of the thumb** (Fig. 342) differs from the others in being complete in itself. It is a saddle-shaped joint. The hand lying supine, the long axis of the joint slants downward and inward. In this direction the trapezium is concave ; at right angles to it convex. The joint is surrounded by a capsule, which is strongest on the dorsal and palmar sides, where the direction of the fibres is longitudinal ; it is weak at the outer anterior end, where it is strengthened by the tendon of the extensor of the metacarpal bone.

Fig. 346.

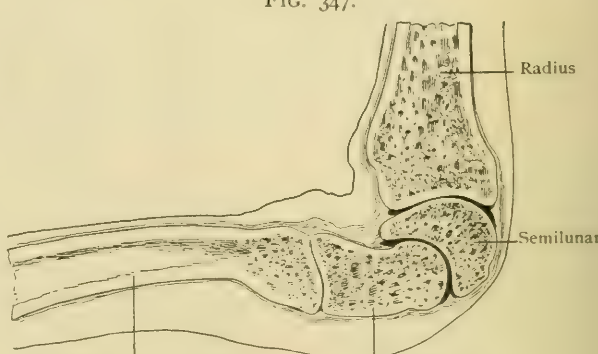


Same as Fig. 345, the hand being flexed.

The **motions** are flexion, extension, adduction, abduction, and circumduction. Rotation in the flexed position may be possible from the imperfect adaptation of the articular surfaces, but can hardly be of practical importance. Flexion is limited by the locking of the palmar projection of the metacarpal against the trapezium ; the other angular motions by the tension of the ligaments.

Movements and Mechanics of the Wrist and Carpo-Metacarpal Articulations.—It is convenient in studying these movements to imagine that the metacarpus follows the motions of the second row of carpal bones. This is true of the index- and middle fingers, but not of the others. The motions of the wrist in the widest sense are flexion, extension, adduction, abduction, and circumduction. The joint is a compound one, egg-shaped above, the scaphoid, semilunar, and cuneiform acting as a meniscus. The motions are best studied by removing the skin and tendons on the dorsal aspect and inserting long pins into the radius, semilunar, and os magnum, and, for some purposes, the scaphoid. The Röntgen rays have been useful chiefly as corroboratory evidence. In *flexion* the motion begins in the upper joint, where it is most extensive ; as it goes on the lower takes part. In *extension*, starting with the arm straight, more than half occurs in the lower joint. *Adduction* (ulnar flexion) (Fig. 348, *B*), owing to the lesser prominence of the ulna, is more free than abduction. The meniscus glides towards the radial side, and in so doing assumes the relation to the radius that it has in extension. The scaphoid touches the radius only by one end, so that its long axis approaches the direction of that of the forearm, and the semilunar leaves the triangular cartilage. The curve of the meniscus broadens, increasing the distance between the ends of the cuneiform and the scaphoid. A small part of the motion occurs in the mid-carpal joint. The unciform, moving with the os magnum, comes nearer to the semilunar. The space

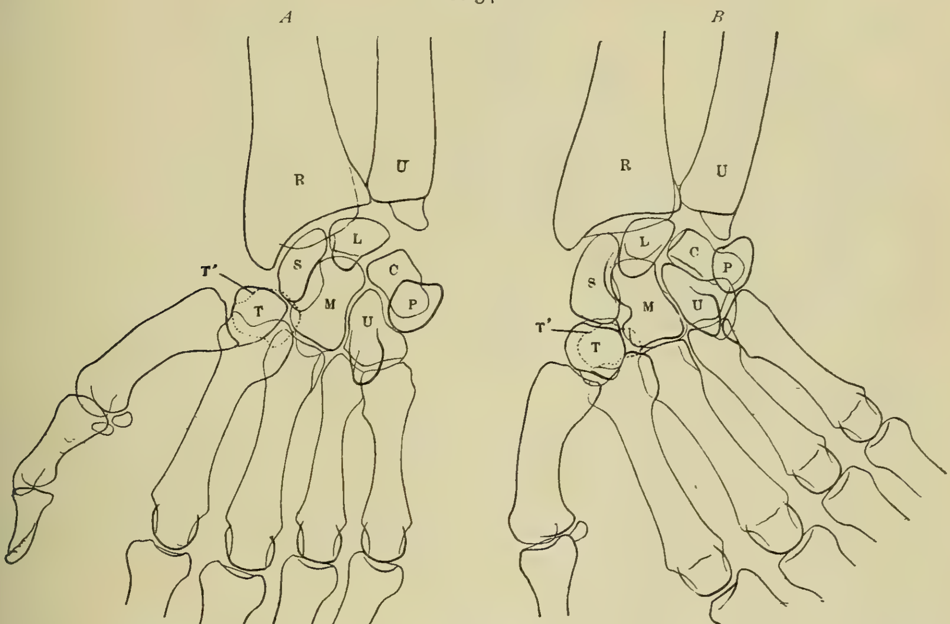
Fig. 347.



Same as Fig. 345, the hand being overextended.

between the neck of the os magnum and the scaphoid enlarges. In *abduction* (radial flexion) (Fig. 348, *A*) the second row of the carpus has a larger share in the motion than in adduction. The meniscus moves to the ulnar side and is flexed, while its ends approach each other, narrowing the arch. The lower end of the scaphoid is crowded against the os magnum and the proximal end of the unciform recedes from the semilunar. Lateral motions do not occur when the wrist is either strongly flexed or extended. The screw surfaces of the cuneiform and unciform are important factors in the combination of antero-posterior and lateral motions ; but the os magnum and unciform, which move together, do not twist in the socket formed by the first row if the latter be fixed. *Circumduction* is a combination of the preceding motions. Though the meniscus moves as a whole, the scaphoid is less closely attached to the semilunar than is the cuneiform.

FIG. 348.



Reduced tracings from skiagraphs, showing the position of the carpal bones. *A*, in radial flexion ; *B*, in ulnar flexion.[1]

Flexion is limited by the tension of the dorsal ligaments ; extension in the upper joint chiefly by the lateral ligaments, in the lower by the locking of the bones of the meniscus against those of the first row. The anterior fibres of the capsule probably assist. Lateral motion is checked in the upper joint by the side ligaments ; in the lower joint it is limited chiefly by the shape of the bones. The number of joints between the carpal bones divide the force of shocks transmitted through the hand.

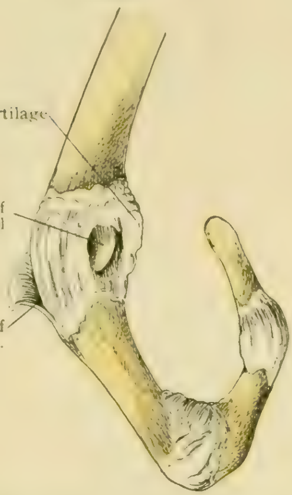
The motions of the carpo-metacarpal joints of the fingers are almost wanting, except for the ring and little fingers. In both these the motion is essentially flexion, most marked in the latter, and, owing to the dorsal convexity of the carpus, tending to oppose the little finger to the thumb.

The **metacarpo-phalangeal articulations** are surrounded by a rather loose *capsule*, which is inserted into both bones pretty close to the articular cartilage. It is weakest on the dorsum, where it is supported by the extensor tendons. It

[1] In tracings from X-ray photographs it is in places very difficult satisfactorily to outline the separate bones, partly because the contours of both surfaces as well as of thick processes are shown, and partly because some bones lie in front of others, owing to the palmar concavity of the wrist. The greatest difficulty is with the respective outlines of the trapezium and trapezoid. In the above figures the outline of the latter is indicated in dotted lines. This confusion is of little practical importance, since the drawings are to illustrate the changes of position between the first row and the forearm on one side and the second row on the other.

springs from little hollows on the sides of the heads of the metacarpals. Longitudinal fibres are distinct at the sides, if sought for from within the joint. The capsule is strengthened on the palmar surface by fibrous or fibro-cartilaginous plates,—the *glenoid cartilages*,—which form the beginnings of the floor of the canals for the flexor tendons (Fig. 350). These plates are firmly fastened to the bases of the phalanges, whose motions they follow, and loosely to the metacarpals. In the thumb the glenoid plate amounts to little or nothing, as the palmar aspect of the joint is chiefly covered by the two *sesamoid bones*, which are firmly held near together by transverse fibres. When sesamoids are present in the other joints, they are lost in the fibrous tissue at the sides of these plates. The glenoid cartilages of the four inner fingers are attached to one another by a series of bands of little strength,—the *transverse metacarpal ligament* (Fig. 351).

FIG. 349.



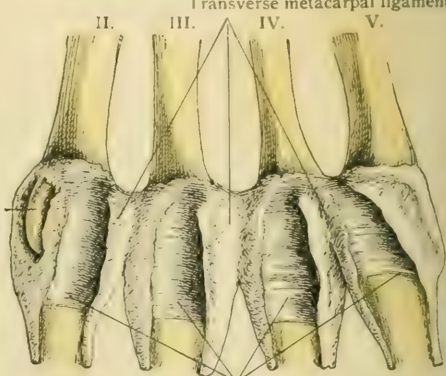
Outer side of right forefinger. The metacarpo-phalangeal joint is opened.

The articular surface of the metacarpal is in the main convex and that of the phalanx concave. They do not make a true ball-and-socket joint, for the long axis of the latter is transverse and at right angles to that of the former, which, moreover, is much broader at its palmar than at its dorsal end. As the glenoid disks are parts of the floors of the canals for the tendons diverging from the middle of the wrist, those of the second and fifth fingers are not squarely placed, but incline to the middle of the hand.

Movements.—When the finger is straight, it can be moved laterally, a little backward, and flexed, as well as circumducted. It can, on the dead hand, be slightly rotated; but this motion does not occur in life. When it is fully flexed, lateral motion is impossible owing to the tenseness of the capsule, which has occurred in two ways,—partly from the fact that in flexion the phalanx rests on the broadest, instead of the narrowest, part of the head, and because, the depressions for the origins of the strongest lateral parts being near the dorsum, these are stretched when the phalanx has travelled round the palmar prominence of the head.

The **interphalangeal articulations** differ from the preceding by the peculiarities of the articular ends and the greater relative strength of the lateral parts of the capsules. The glenoid cartilages are small. There is no lateral motion. They are the purest hinge-joints in the body.

FIG. 350.

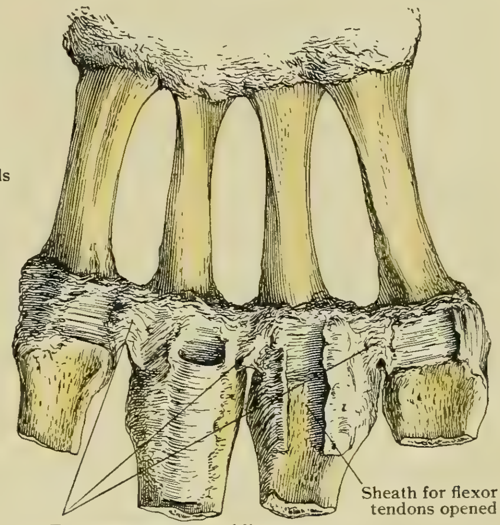


Palmar aspect of right metacarpo-phalangeal joints. Sheaths for flexor tendons opened.

The Surface Anatomy of the Wrist and Hand.—The joint between the forearm and the carpus can be approximately indicated by a line either on the back or the front, but more accurately on the former, starting from the head of the ulna, running nearly transversely, but with a slight upward bend, to near the radial styloid, and then sweeping downward to its tip. The first row of carpal bones can be made prominent on the back by flexing the wrist. The hollow

on the dorsum of the os magnum is distinct, and some indication of the mid-carpal joint may be felt near it. "Slightly external to the middle of the hand is a prominence, sometimes indistinct, but often very well marked, formed by the styloid process on the base of the third metacarpal bone at its articulation with the os magnum" (Thane and Godlee). On the palmar side the pisiform can be felt just at the beginning of the hypothenar eminence. When the hand is flexed and the muscles relaxed, it is easily moved from side to side. The unciform process can be indistinctly felt below it. The tubercle of the scaphoid is felt with difficulty below and internal to the radial styloid, and at the beginning of the thenar eminence (the ridge on the trapezium) more clearly. The position of the annular ligament may be deduced from these points, and it may be felt by pressure on the hand. It is a general rule for the joints between the metacarpals and the phalanges, as well as for those between the latter, that the more distal moves on the proximal, and that, therefore, the prominence of the knuckle in flexion is made by the head of the metacarpal. All the metacarpo-phalangeal joints can be made out from the dorsum. The sesamoid bones of the thumb are felt with difficulty.

FIG. 351.



Palmar aspect of right metacarpo-phalangeal joints. Sheath for flexor tendons on one finger opened; on adjacent finger still closed.

The web of the fingers lies about thirteen millimetres distal to the palmar aspect of the metacarpo-phalangeal joints. That of the index-finger is about midway between the transverse furrow reaching the radial side of the hand and the first crease on the finger; those of the other fingers are in the same relation to the second furrow and the respective creases. The interdigital joints are slightly distal to the upper line of the complicated creases of the first joints and to the single line of the creases of the second row.

PRACTICAL CONSIDERATIONS.

The Wrist-Joint.—The radio-carpal has the greatest amount of motion of the three rows of joints that intervene between the metacarpus and the forearm. Its strength is not derived from the shallow concavity on the lower end of the radius, or from the ligaments which, taken together, compose the capsule, but rather from the tough fibrous tissues forming the sheaths of the large number of tendons that pass over the anterior and posterior aspects of the joint and are closely united to the bones. It escapes frequent injury, also, because of the numerous bones that enter into the carpus, which by their gliding motion one upon the other diffuse force received through falls upon the hand; because of the same effect produced by the movement of the mid-carpal joint (intracarpal of Dwight), which takes up part of the force in overextension of the hand before it reaches the wrist; and because of the absence of any long rigid lever on the distal side of the joint.

Dislocation *backward* is by far the most common, on account of the frequency of falls upon the hand. The diagnosis from Colles's fracture is made by observing that in dislocation: (1) the anterior swelling is nearer the ball of the thumb; (2) the posterior swelling is more sharply defined at its upper edge; (3) the styloid process of the radius is nearer the hand than that of the ulna; (4) the distance from

it to the head of the metacarpal bone of the index-finger is shortened ; (5) the antero-posterior diameter of the wrist is increased ; (6) the flexion and immobility of the wrist are greater.

In dislocation *forward* the posterior swelling (the sharp border of the radius and ulna) approaches the hand ; the rounded prominence of the carpus is on the front of the wrist ; the antero-posterior diameter is increased and the stylo-metacarpal measurement is lessened.

Outward (radial) dislocation of the wrist is resisted by the contact of the scaphoid with the styloid process of the radius and by the internal lateral ligament. Inward dislocation would theoretically be easier, as there is no bony obstacle, and as adduction may be effected to a greater extent than abduction, and with greater power, on account of the leverage afforded by the projection of the cuneiform and pisiform bones on the inner side of the wrist. It is for this reason that the hand commonly assumes the position of adduction and the little finger becomes inclined towards the ulna when, from disease or other cause, the muscles lose the influence of volition and exercise an uncontrolled sway over the part (Humphry). Dislocation in either lateral direction is, however, very rare.

Spontaneous subluxation forward is a condition thought to be associated with hard manual labor in which the strong anterior ligament becomes stretched and the radial side of the carpus is displaced forward and upward. This is followed, in accordance with a general law of growth (page 104), by an overgrowth of the posterior portion of the lower end of the radius, from which the normal opposing pressure of the carpus has been removed. The lower end of the ulna becomes unduly prominent.

Disease of the wrist-joint is frequently tuberculous, but may be septic or rheumatic or gonorrhœal in its origin. As the joint-cavity does not include the epiphyseal lines of either the radius or ulna, the synovial membrane being attached to the margins of the epiphyses, disease and injury of the latter do not of necessity involve the joint. The circumstances already detailed that protect the joint from dislocation also protect it from sprains and lessen the frequency of traumatic synovitis and of the sequelæ of traumatism.

Disease of any variety once established is apt to extend to the various synovial pouches of the carpus on account of their proximity, to involve the flexor and extensor tendon sheaths for the same reason, and to result, in accordance with its character, in either extensive disorganization or much limitation of motion. The flexors and extensors on the front and back of the wrist act with about equal force, and therefore but little displacement occurs.

The swelling usually shows itself first on the dorsum through the thinner posterior ligament, the joint being nearer the surface on that aspect.

Landmarks.—The line of the wrist-joint is convex upward. A straight line drawn between the two styloid processes is oblique downward and outward. It unites the two extremities of the arc which represents the line of the joint. The highest point of that arc is a half-inch above the interstyloid line.

If a knife were introduced horizontally below the tip of the styloid process of the ulna, it would open the wrist-joint ; below the styloid of the radius, it would strike the scaphoid.

The remaining landmarks are described on page 621.

The Joints of the Carpus, Metacarpus, and Phalanges.—As the intermediate ligaments uniting the separate bones of each row of the carpus are all transverse, and do not pass from one row to another, the mid-carpal (intracarpal) joint permits of considerable motion in both flexion and extension. It undergoes dislocation with extreme rarity, and usually only as a result of a degree of force sufficient to stretch or tear tendons and ligaments.

Dislocation of the second row of the carpus *forward* is prevented by the manner in which the concave surfaces of the trapezium and trapezoid rest upon the posterior convex facet of the scaphoid, as well as by the undulating manner in which the side of the unciform is disposed with regard to the side of the cuneiform. Displacement *backward* is prevented by the manner in which the round head of the os magnum and the convex posterior and upper surface of the unciform are let into

the hollow formed in the anterior and inferior surfaces of the bones of the first row (Humphry).

The joints between the individual bones of the carpus allow of but little motion, and much force is needed to produce displacement of those bones. In the order of frequency the os magnum, semilunar, scaphoid, pisiform, trapezium, trapezoid, and unciform have been reported as separately dislocated. It is interesting to note in relation to the order of frequency that the middle finger is the longest, and is the one most exposed to injury and to force applied to the fingers ; its metacarpal bone is the longest ; it articulates directly with the strongest carpal bone,—the os magnum,—and it, in its turn, with the semilunar, which unites with the scaphoid in connecting the hand with the forearm. In reported cases the pisiform was thought to be dislocated secondarily after the rupture of the tendon of the flexor carpi ulnaris below the bone.

The other separate carpal luxations have but little anatomical interest.

Disease of the mid-carpal joint is usually tuberculous, and is apt to begin in or extend to the os magnum because—1. It is the bone most exposed to traumatism (*vide supra*), receiving the effects of injury to three metacarpal bones. 2. The joint participates in the movements of flexion and extension of the wrist, which are partly limited by the portion of the oblique fibres (both radial and ulnar) of the anterior annular ligament (page 325) and by some of the radial fibres of the weak posterior ligament, which are attached to the os magnum. 3. The slight rotation permitted in the mid-carpal joint is around a vertical axis drawn through the head of the os magnum. A very slight enlargement of the bone would tend to pinch and bruise the synovial membrane between it and the trapezoid, those two being more closely bound together than any of the other bones. It has been noticed (Mundell) that the point of greatest tenderness in these cases of carpal tuberculosis was in a line between the index- and middle fingers, corresponding to the junction of the os magnum and the trapezoid. Barwell says that in tuberculosis of the wrist-joint the point of special tenderness is on the outer side of the extensor indicis tendon. This is on the same line, and, in cases in which the carpus has become involved, would correspond to the same point of junction.

Dislocations of the metacarpal bones from the carpus usually involve single bones, are incomplete, and are in the backward direction. The wavy, irregular outline of the distal edge of the carpus, the dovetailing of the metacarpals and carpals by means of the alternating convexities and concavities, and the strength of the interosseous and transverse metacarpal ligaments sufficiently explain the infrequency of dislocation of the metacarpus as a whole.

Dislocations of the metacarpo-phalangeal and interphalangeal joints amount to "nearly thirty per cent. of all dislocations" (Stimson). Backward displacement of the proximal phalanx of the thumb is the most frequent and the most important. The cause is usually exaggerated extension of the phalanx, which carries its proximal end up onto the dorsum of the metacarpal bone above the articular surface. The relation to the muscles of the thumb is so important that the luxation will be described in that connection (page 617).

Dislocations between the phalanges usually occur at the first phalangeal joint, and in the backward direction, as the cause is commonly a fall upon the palmar surface of the finger in extension.

THE LOWER EXTREMITY.

The Pelvic Girdle.—This consists of the two innominate bones, which join each other in front, and the sacrum behind. While the thoracic girdle is adapted to freedom of motion, the pelvic is fitted for strength and support.

The study of the innominate bone should be preceded by a general idea of the pelvis. A plane between the promontory of the sacrum and the top of the pubes divides the pelvis into the *false pelvis* above, formed chiefly by the ilia, and the *true pelvis* below. The latter presents the sacrum and coccyx behind, the arch of the pubes in front and below, and the tuberosity of the ischium at the side. Behind this is the sacro-sciatic notch, much reduced by ligaments. On the sides are the hip-joints, and towards the front the obturator or thyroid foramen.

THE INNOMINATE BONE.

This[1] consists originally of the *ilium*, *pubis*, and *ischium*, each of which forms a part of the hip-joint, but which fuse so completely that the lines of union are not usually to be seen in the adult. The ilium forms the upper and posterior part of the bone, the pubis the front, and the ischium the inferior. The two latter enclose the obturator foramen.

The Ilium.—The ilium,[2] a plate of bone forming the side of the false pelvis and a part of the true, may be said to have four borders. The **superior border,** or **crest,**[3] very much the longest, is convex upward and outward. It connects two tubercles, the *anterior* and *posterior superior spines* of the ilium, of which the former is a knob overhanging the concave anterior border and giving attachment to Poupart's ligament and the sartorius, while the latter is less prominent. The crest has a double lateral curve, the front half being convex externally and the posterior internally. It is thicker at the ends than in the middle, and presents also a thickening near the middle of each curve, projecting on the convex side. There is an external lip, from the whole length of which springs the fascia lata of the thigh, an internal lip, and an intermediate space. The **anterior border** is short, rounded, and concave, descending to the *anterior inferior spine*, a knob a little above the border of the acetabulum giving origin to the straight head of the rectus femoris and a part of the ilio-femoral band of the capsule of the hip-joint. The **posterior border,** very short and also concave, ends in the *posterior inferior spine*, an ill-marked angle at the bottom of the surface that joins the sacrum. The **inferior border** consists anteriorly of an attached part, which meets the other bones in the acetabulum, and behind this of a free concave part, which bounds the upper part of the *great sacro-sciatic notch.*[4] The ilium might also be described as consisting of an expanded portion, narrowing below to a stem, which joins the other bones in the acetabulum. Its upper part follows the curves of the crest.

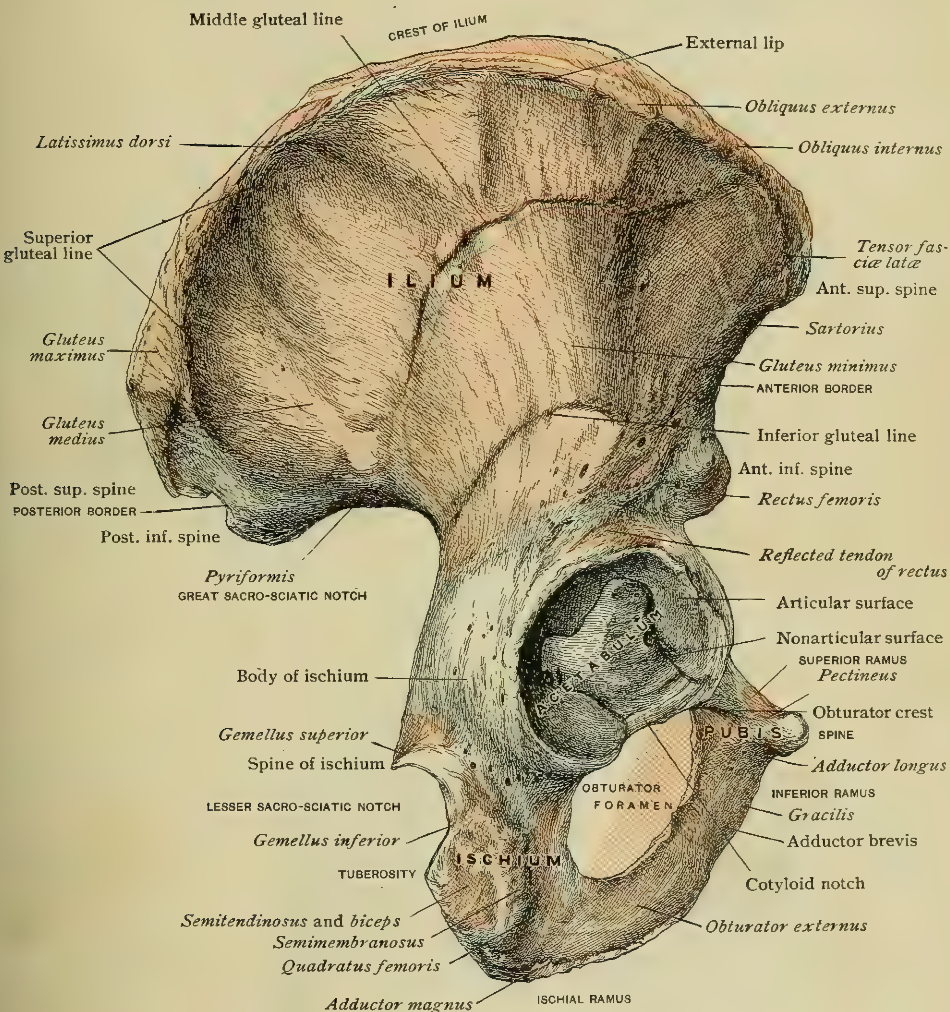
The **lateral** or **outer surface** is crossed by the three *curved* or *gluteal lines*, convex above and behind, all ending at or near the sciatic notch. The *superior*, much the strongest, arises from the crest at the middle of its second curve and ends a little in front of the posterior inferior spine, marking off a raised rough surface behind its upper two-thirds. The *middle* begins at the crest, one or two inches from the anterior superior spine, and ends near the top of the notch. The *inferior*, the faintest, starts a little above the anterior inferior spine and is lost near the front of the notch. The three gluteal muscles, maximus, medius, and minimus, arise respectively behind these three lines in the order given. A slight groove for the reflected tendon of the rectus femoris, starting at the anterior inferior spine, runs backward above the acetabulum.

The **ventral** or **inner surface** is divided into an upper posterior and a lower anterior part by the *ilio-pectineal line*[5] in front, and a rough border continuing it. The former is a line beginning on the pubis and continued across the

[1] Os coxae. [2] Os ilium. [3] Crista iliaca. [4] Incisura ischiadica major. [5] Linea arcuata.

ilium to the sacrum, separating the true pelvis below from the false above. All of the ilium above this line, except a small part posteriorly, is a smooth, shallow concavity, the *iliac fossa*,[1] which contains the iliac muscle. It ends in front in a groove between the anterior inferior spine of the ilium and the *ilio-pectineal eminence*,[2] a swelling above the inner part of the acetabulum made by both the ilium and the pubis at their point of meeting. The bone is very thin at the middle of the fossa. The lower half of the inner surface of the ilium may be subdivided into two very dissimilar parts. The front one, forming the wall of the true pelvis, opposite a part

FIG. 352.



Right innominate bone, outer aspect.

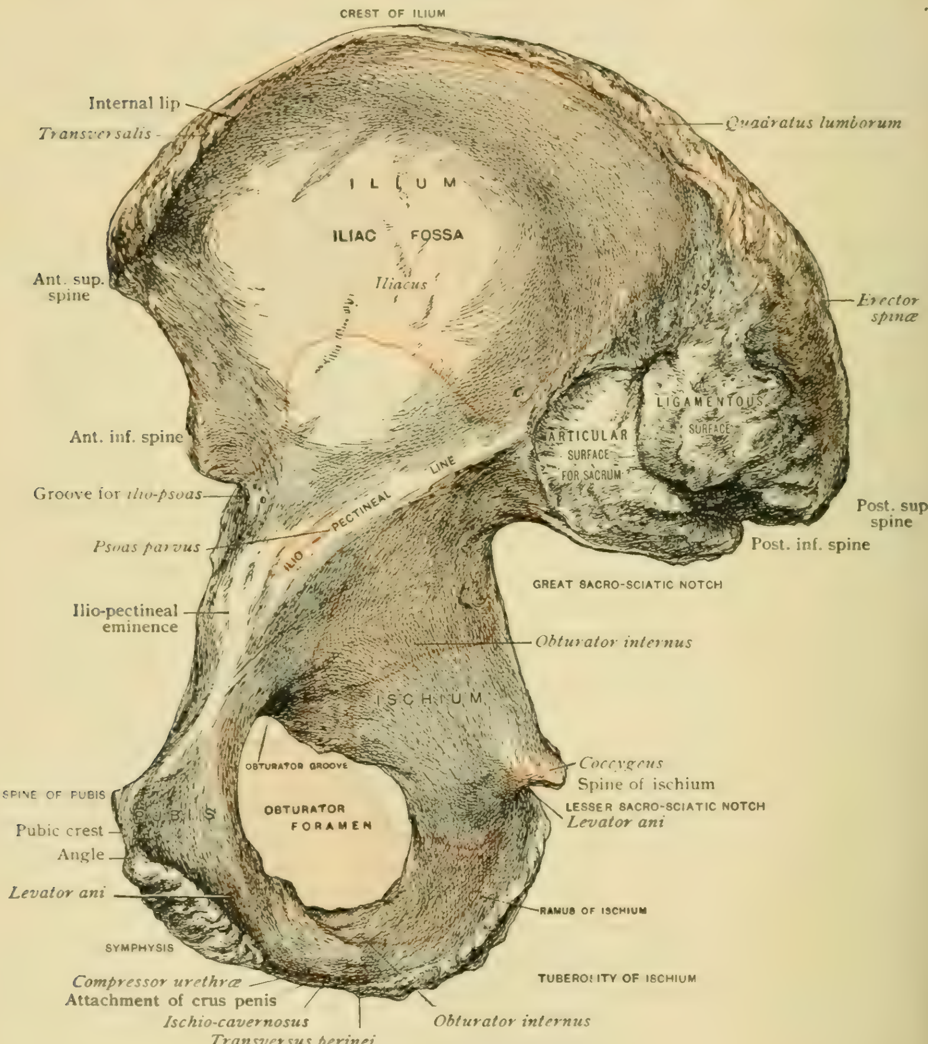
of the socket and above the sciatic notch, is smooth ; the posterior is rough. The latter presents anteriorly the rough and pitted *auricular surface*[3] corresponding to that of the sacrum. A narrow depression, the *pre-articular groove*, bounds this on the smooth surface, receiving the fibres of the anterior sacro-iliac ligament. Behind the auricular surface is a rough area of a different character with an elevation at or below the middle of the preceding surface. This area serves for the attachment of the strong posterior sacro-iliac ligaments. Still farther back the bone has a smoother finish where it gives origin to the erector spinæ. The ilium has several large

[1] Fossa iliaca [2] Eminentia iliopectinea. [3] Facias auricularis.

nutrient foramina ; one on the inside of the lower hind part of the iliac fossa runs forward, one or two on the outside near the anterior inferior spine run backward, and one near the middle of the second curved line runs downward.

The Pubis.—The pubis[1] (*os pectinis*) has a flat squarish *body*, which, meeting its fellow at the symphysis, forms the front wall of the pelvis, and two *rami*, the superior joining the ilium and the inferior joining the ischium. The median end of the **body**[2] is wholly taken up by a rough oval area, the *symphysis pubis*, bearing the fibro-cartilage of the joint. The *spine*[3] of the pubis is a pointed tubercle, projecting

FIG. 353.



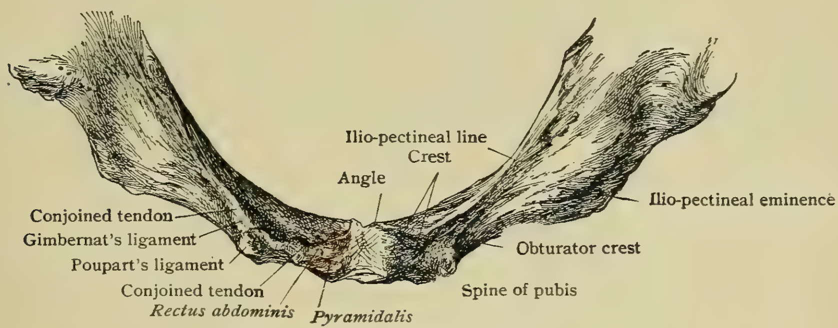
Right innominate bone, inner aspect.

forward from the front of the upper border of the bone some two centimetres from the symphysis, to which Poupart's ligament is attached. A ridge runs from this obliquely backward and inward to the posterior end of the top of the symphysis, which, together with the rough surface internal to it, constitutes the *crest*. The term *angle* is applied to the line of junction of this surface with the symphysis. The **superior ramus**[4] is prismatic, having an antero-superior, an inferior, and a posterior side. It enlarges as it runs outward to form a part of the socket. The *ilio-pectineal*

[1] Os pubis. [2] Corpus ossis pubis. [3] Tuberculum pubicum. [4] Ramus superior.

line starts from the spine and runs obliquely backward and outward to the ilium. The triangular antero-superior side of the ramus, narrow at the inner end, broad at the outer, concave from side to side, convex from before backward, is bounded behind by the ilio-pectineal line, in front by the *obturator crest*,[1] which runs from the

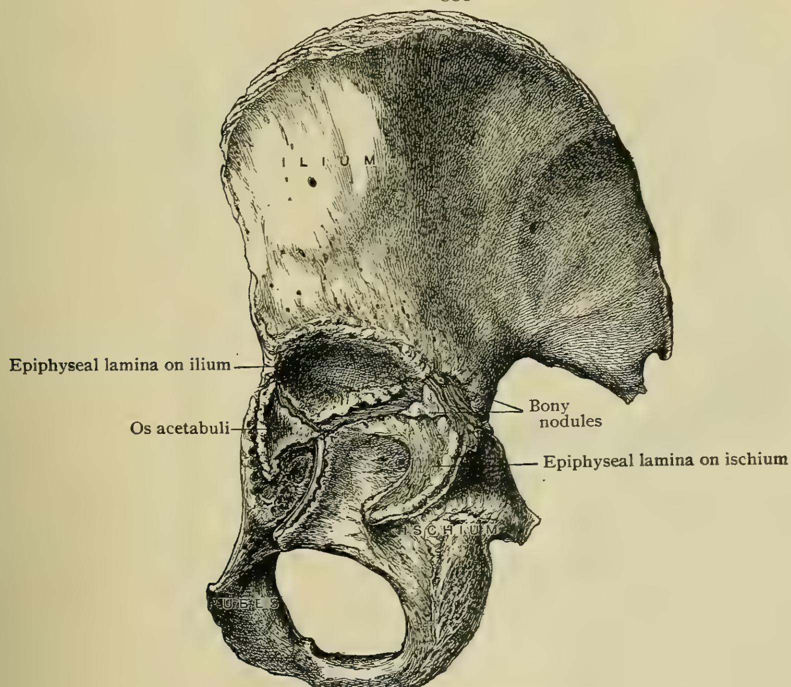
FIG. 354.



Region of symphysis pubis from above.

spine to the inner border of the acetabular notch, and externally by a swelling at the upper inner part of the socket,—the *ilio-pectineal eminence*. The posterior side, broad at the inner end and narrow at the outer, is quite smooth. The inferior border is marked by the broad *obturator groove*[2] above the foramen, passing from behind for-

FIG. 355.



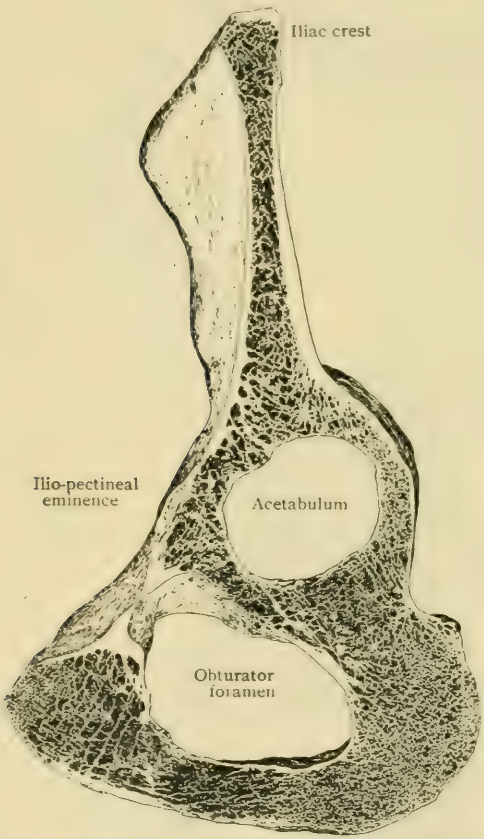
Innominate bone at about fifteen years.

ward and inward for the obturator vessels and nerve. The **inferior ramus**,[3] flat and thin, rough in front, smooth behind, extends backward and outward to join the ramus of the ischium. It is constricted just above the point of union. The inner edge, forming part of the pubic arch, is somewhat everted.

[1] Crista obturatoria. [2] Sulcus obturatorius. [3] Ramus inferior.

The Ischium.—The ischium,[1] the thickest and most solid part of the bone, consists of a *body*, chiefly concerned with the acetabulum, a *tuberosity*, and a *ramus*. The **body**, continuous above with the ilium, forms the front of the *great sciatic notch*,[2] below which is the sharp *spine* of the ischium pointing backward and inward for the lesser sacro-sciatic ligament. The **tuberosity**[3] is a great thickening of the back of the lower end of the body of the ischium which bears the weight in sitting. It is broad above and behind, narrowing in front as it passes into the ramus. It extends but little onto the inner side of the bone, which otherwise is smooth. Its inner lip receives the great sacro-sciatic ligament and its falciform prolongation. A smooth surface (in life coated with cartilage) passes from the inside of the back of the bone just below the spine and above the tuberosity, forming the *lesser sciatic notch*,[4] occupied by the tendon of the obturator internus. In front of this, under the acetabulum and above the tuberosity, is a groove for a part of the obturator externus. The upper part of the tuberosity is divided into an upper and front area for the origin of the semimembranosus, and one behind and below it for the semitendinosus and biceps. Below these, extending onto the ramus, is a surface for the adductor magnus. The **ramus**[5] is a strip of bone running forward to meet the inferior ramus of the pubis. The lower edge, forming the margin of the *subpubic arch*, is twisted outward and rough. The border towards the foramen is relatively sharp. The line of junction of the rami of the ischium and pubes can be distinguished by the greater breadth of the former.

FIG. 356.



Oblique sagittal section of right innominate bone passing through bottom of acetabulum; inner surface.

The **acetabulum,** the socket for the hip, is a deep hemispherical cavity with a raised border, imperfect below. The imaginary axis of the cavity runs upward, inward, and backward. It is formed by all three bones, the ischium contributing the most and the pubes the least. The lines of union are sometimes seen on the smooth posterior surface in the adult. The cavity is only in part articular. In shape this portion may be compared to a horseshoe beaten concave and fitted into the cavity with the two ends pointing downward, enclosing a non-articular cavity at a somewhat deeper level, which extends more than half-way up the back of the socket. The bone at the bottom of the cavity is very thin. The articular strip is broadest above and behind the middle and narrowest in front. Of the two ends of this articular strip the posterior is the more prominent, overhanging a groove leading into the non-articular hollow from below. The front one has no corresponding projection. The border of the acetabulum is formed by the convexity of this horseshoe-shaped strip, and consequently is wanting below. The interruption is the *cotyloid notch*.[6] The

[1] Os ischii. [2] Incisura ischiadica major. [3] Tuber ischii. [4] Incis. isch. minor. [5] Ramus inferior. [6] Incisura acetabuli.

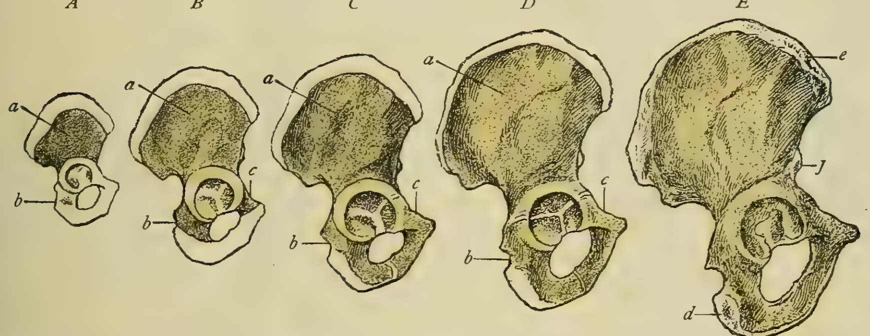
border rises from the surface of the bone distinctly below and to a less degree behind and above.

The **thyroid** or **obturator foramen**[1] is a large oval opening, with the larger end above and the long axis running downward and outward, bounded by the pubis and ischium. A little tubercle, seen best from the inner side, marks the upper limit of the ischium. Above is the *obturator groove* under the ramus of the pubis. It is closed by a membrane, except under the groove.

Structure.—The innominate bone is, as a whole, very strong. The two thin places are in the middle of the ilium and of the cotyloid cavity. It is very thick round the joint wherever pressure may be transmitted through the head of the femur. Sections show radiating trabeculæ from the socket connected by concentric lines. The bone is very thick in a line from the socket to the outer expansion of the iliac crest, which runs nearly vertically in the upright position. It is very strong also at and behind the auricular surface.

Development.—A centre for the ilium appears early in the third fœtal month above the acetabulum and spreads quickly through the upper part of the bone. One for the ischium appears below the socket, usually before the end of the same month. One for the pubis comes decidedly later in the iliac ramus. It is said to appear from the fourth to the fifth month, but it may not be present till the sixth. *At birth* there is still much cartilage around and between the bony expansions from these centres. The rami of the pubis and ischium unite at about eight years or earlier, but the suture may be visible on the inside at eighteen. Ossification commences by several centres in the Y-shaped cartilage separating the bones in

FIG. 357.



Ossification of innominate bone. *A*, at third fœtal month; *B*, at birth; *C*, during first year; *D*, at six years; *E*, at about fifteen years. *a*, chief centre for ilium; *b*, chief centre for ischium; *c*, for pubis; *d*, for tuberosity of ischium; *e*, for iliac crest; *f*, for anterior inferior spine.

the socket at an uncertain date, probably before ten years. One of these centres, much larger than the rest, the *os acetabuli*, persists at the front of the cavity between the pubis and ilium till perhaps fifteen, when union has made much progress between the various parts of the acetabulum. The lines of junction may be seen on the inside at seventeen or eighteen, that between the pubis and ischium persisting longest. Secondary centres come about puberty for the crest of the ilium, the anterior inferior iliac spine, the symphysis pubis, and the ischial tuberosity. They are fused at twenty, excepting, perhaps, that for the crest of the ilium, the union of which may be delayed; the suture marking its presence is one of the last in the body to disappear.

JOINTS AND LIGAMENTS OF THE PELVIS.

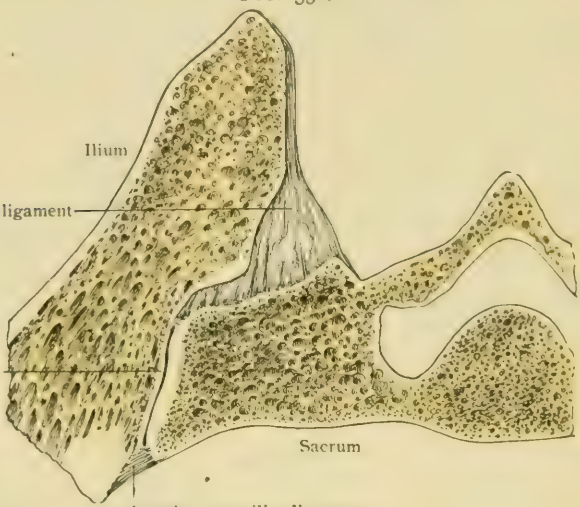
These may be divided into (1) those connecting the ilium with the sacrum and last lumbar vertebra, (2) those connecting the pubic bones at the symphysis, and (3) the ligaments forming the lateral walls,—the sacro-sciatic ligaments and the obturator membrane.

[1] Foramen obturatum.

THE SACRO-ILIAC ARTICULATION.

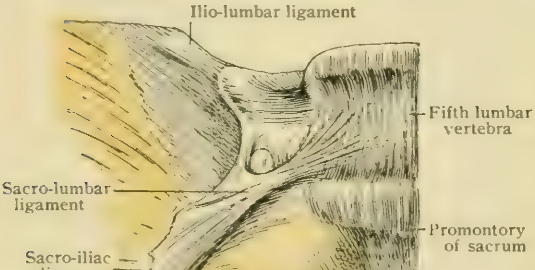
The sacro-iliac articulation, often improperly called the *sacro-iliac synchondrosis*, partakes of the nature of both a true and a half-joint. The opposed surfaces of the sacrum and ilium vary greatly in shape. The sacrum is broader in front than behind, so that the line of the joint slants inward as well as backward ; but occasionally in some part it is a little broader behind than in front. Often there is an outward swelling between the borders, so that a part of the sacrum is received into a hollow in the ilium, and a transverse cut of the joint shows a sinuous line. Perhaps quite as often the ilium projects into the sacrum. In any case, as a rule, there is a certain amount of interlocking. The opposed surfaces are covered with cartilage. The layer on the sacrum, from one to two millimetres thick, is at least twice as thick as the other, and, though generally reckoned fibro-cartilage, has much the appearance of hyaline. The two are separated by a synovial cavity, which is enclosed by the sacro-iliac ligaments. The size of this cavity is very uncertain. It may extend backward beyond the auricular surfaces, occupying on the ilium a part of the space usually serving for the origin of the posterior sacro-iliac ligaments, or it may be encroached upon by fibres. Sometimes, before old age, the joint is replaced by bone.

FIG. 358.



Horizontal section through right sacro-iliac joint.

FIG. 359.



Anterior view of the sacro-iliac joint and of the last lumbar vertebra.

The fibres around the joint are severally named according to position. The **posterior sacro-iliac ligament** (Fig. 358) is very important. It comprises many layers of strong fibres, filling up the depths of the cleft between the sacrum and the overhanging ilium, extending from the rough area on the latter behind the auricular surface to the back of the lateral masses of the sacrum, nearly or quite to the posterior sacral foramina below the three upper sacral vertebræ. Those of both sides

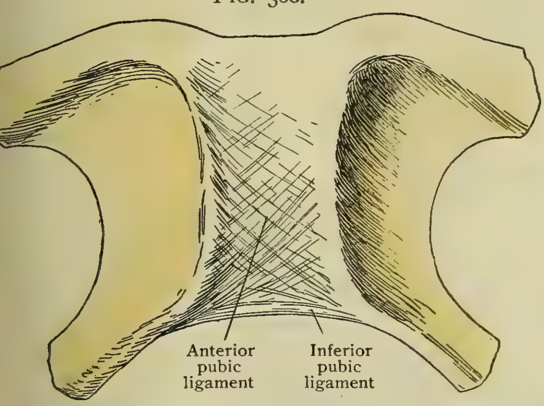
resist any tendency of the weight of the body to force the sacrum forward. A rather distinct superficial band, the **oblique sacro-iliac ligament**[1] (Fig. 362), passes from the posterior superior iliac spine to the second and third sacral vertebræ. **Anterior** and **superior** fibres are spread about the joint, and require no special description. Some of them go to the pre-auricular sulcus of the ilium.

The **ilio-lumbar ligament**[2] (Fig. 359) is a triangular band of strong fibres diverging from the apex and the front surface of the transverse process of the last lumbar vertebra to the top of the crest of the ilium opposite to it and to the anterior surface, where it mingles with the anterior sacro-iliac fibres. A more or less distinct bundle of diverging fibres to the top of the sacrum near the joint with the ilium is the **sacro-lumbar ligament** (Fig. 359).

THE SYMPHYSIS PUBIS.

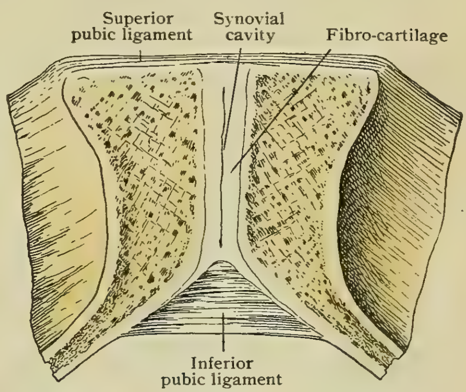
The symphysis pubis is generally a typical half-joint, the fibro-cartilage coating the opposed pubic surfaces being very dense and the central cavity small. In section it appears as a linear cleft nearer the back than the front. Sometimes, however, especially in women, a part of the surfaces is coated with hyaline cartilage. The total breadth of the soft parts (greater in woman than in man) rarely exceeds five millimetres. The cartilages are ensheathed in fibres, the deeper parts of which

FIG. 360.



The symphysis pubis, anterior surface.

FIG. 361.



Frontal section through the symphysis pubis.

are inseparable from them: those above and behind are of little consequence. The anterior ones are in several layers, being in part composed of fibres from the aponeurosis of the external oblique and of fibres of origin of the rectus. They are in the main transverse, but those from the obliques run downward and inward, sometimes making a distinct decussation. The *inferior* or *subpubic fibres* are collected into a dense transverse band, bounding by the lower side the pubic arch and being joined by the upper to the fibro-cartilage.

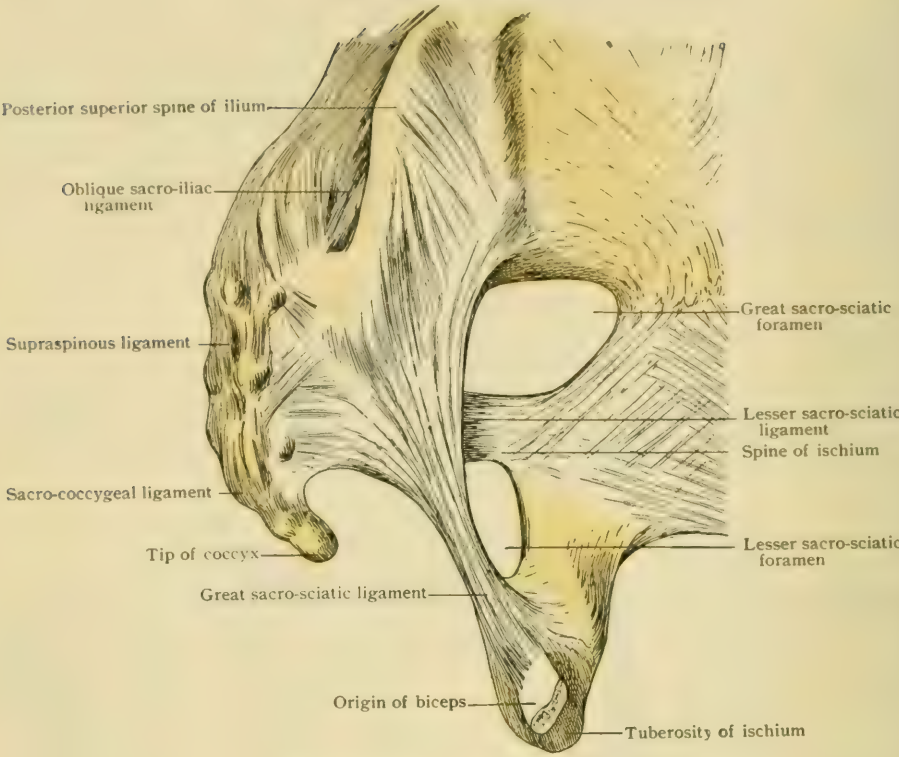
THE SACRO-SCIATIC LIGAMENTS.

These are two layers of fibres passing from the sides of the sacrum to the ischium and forming a partial wall for the pelvis at the sacro-sciatic notch, where the bony walls are wanting.

The **great** or **posterior sacro-sciatic ligament**[3] (Fig. 362) is external to the lesser, which it conceals to a large extent. It arises from the outer surface of the pelvis, beginning at the inferior posterior spine of the ilium, where its fibres mingle with those of the posterior sacro-iliacs, then from the posterior edge of the border of the three lower pieces of the sacrum and from one or two of the coccyx. From this broad origin it narrows as it passes forward, and at the same time twists so that the outer surface becomes the inferior as it is inserted into the under side of the tuberosity of the ischium. As it reaches the tuberosity the fibres at its inner

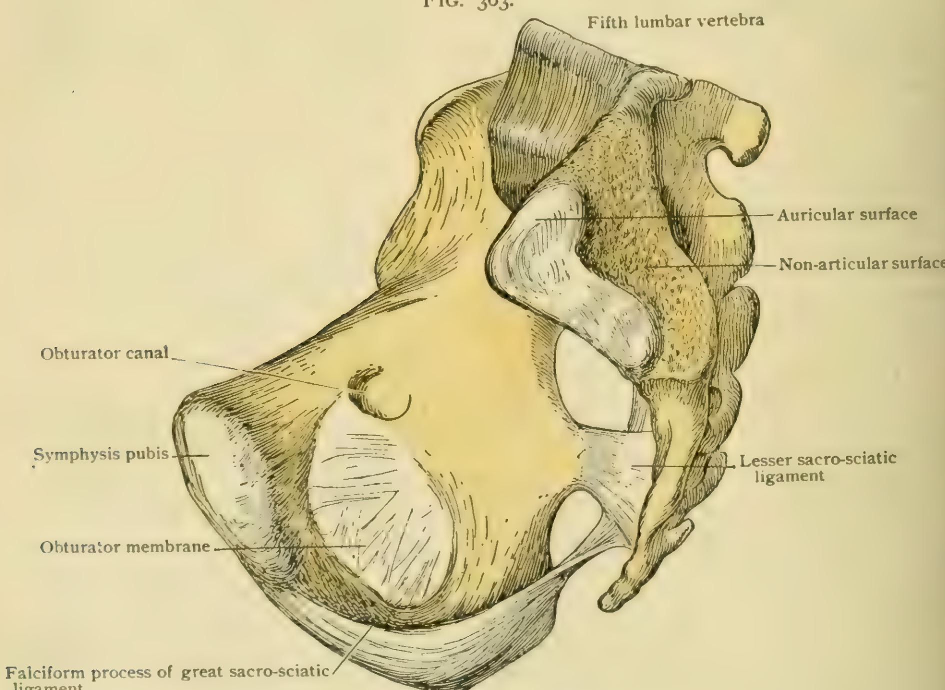
[1] Lig. sacroiliacum posterius longum. [2] Lig. iliolumbale. [3] Lig. sacrotuberosum.

FIG. 362.



External surface of the sacro-sciatic ligaments.

FIG. 363.



Internal surface of the sacro-sciatic ligaments, showing the falciform continuation of the great.

border become raised from the rest and are inserted into the inner border of the ramus of the ischium, from which they rise in a fold, the *falciform ligament*, within the pelvis, continuous with the obturator fascia. The ligament at its insertion into the tuberosity is continuous with the fibres of origin of the biceps.

The **lesser** or **anterior sacro-sciatic ligament**[1] (Fig. 363), much the smaller, is situated internally to the great, springing from the edge of the sacrum below the junction with the ilium and from the side of the upper part of the coccyx, being more or less continuous with the interior surface of the great. It narrows to its insertion into the spine of the ischium.

The **great sacro-sciatic foramen**[2] (Fig. 362) is bounded above by the ilium, in front by the ilium and the ischium, behind by the great ligament, and below by the lesser. It transmits the pyriformis muscle, the gluteal, sciatic, and internal pudic vessels and nerves, and the nerves to the obturator internus and quadratus femoris.

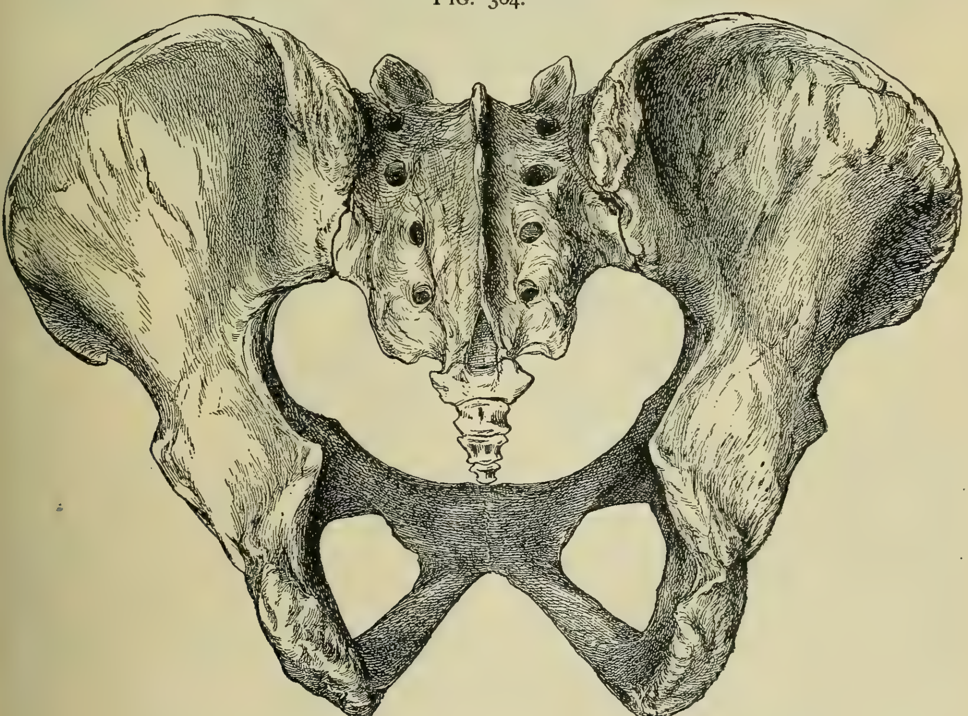
The **lesser sacro-sciatic foramen**[3] (Fig. 362) is bounded in front by the body of the ischium, above by the lesser ligament, and below and behind by the oblique border of the great. Through it pass the obturator internus muscle, the internal pudic vessels and nerve, and the nerve to the obturator internus.

The **obturator membrane**[4] (Fig. 363) is attached to the margin of the foramen of that name, which it completely closes, except for a small space at the top of the groove under the ramus of the pubis. Sometimes there are perforations. The attachment at the inner side is directly to the sharp edge of the rami of the pubis and ischium. At the outer border it passes into the periosteum lining the pelvis.

THE PELVIS AS A WHOLE.

The promontory of the sacrum and the ilio-pectineal line separate the *true pelvis*[5] below from the *false*[6] above. The latter is bounded by the lower lumbar vertebræ

FIG. 364.



The pelvis from behind.

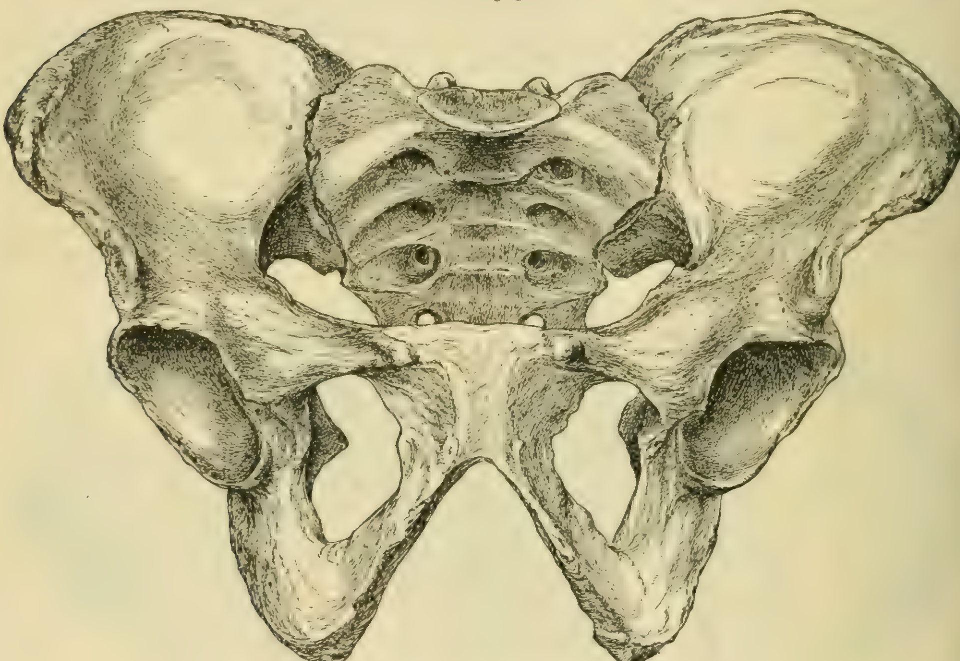
and by the flaring ilia. The true pelvis is bounded by the sacrum and coccyx behind, by the bodies and symphysis of the pubis in front, and by the sacro-sciatic ligaments,

[1] Lig. sacrospinosum. [2] Foram. ischiadicum majus. [3] Foram. isch. minus. [4] Membrana obturatoria. [5] Pelvis minor. [6] Pelvis major.

the ischia, part of the ilia, and the pubic rami and obturator membrane at the sides and front. The plane just described as separating the true and false pelvis is the *plane of the inlet*[1] of the latter. Its greatest individual variations are due to the greater or less projection forward of the sacral promontory. The *outlet*[2] is bounded behind by the coccyx, from the sides of which the great sacro-sciatic ligaments pass to the ischial tuberosities, thence by the rami of the ischia and pubes, forming the pubic arch, and by the subpubic ligament below the symphysis. It is evident that these planes converge in front and that the axis of the pelvis (an imaginary line in the centre, perpendicular to an indefinite number of intermediate planes) must be a curved one.

The Position of the Pelvis.—The plane of the inlet of the pelvis is inclined to the horizon about 60° when the body is upright. This inclination varies according to the figure and to the individual peculiarities of the pelvis itself. Hermann von Meyer's *conjugata vera*, a line from the top of the symphysis to the line usually

FIG. 365.



Male pelvis from before.

found in the third sacral vertebra, runs at about 30° with the horizon. This is a more trustworthy angle than that of the plane of the inlet ; but even this is not constant. It is better to try to determine the proper position of every pelvis for itself than to attempt to make all conform to one angle, which for these reasons is impossible. The two borders of the cotyloid notch should be put in the same level, which will bring the anterior superior spines of the ilia into the same vertical plane as the spines of the pubes. The tip of the coccyx should be at about the level of the top of the symphysis ; owing to the many variations of the former, however, its position must be uncertain. The height of the promontory above the symphysis is about 9.5 centimetres (3¾ inches) in man and about 10.5 centimetres (4⅛ inches) in woman.

The **diameters** of the true pelvis of woman are of great practical importance in midwifery. The standards are the *antero-posterior*, the *transverse*, and the *oblique* (the latter from the sacro-iliac joint to the acetabulum of the opposite side) measured at the inlet, the outlet, and at an intermediate plane.

[1] Apertura pelvis superior. [2] Apertura pelvis inferior.

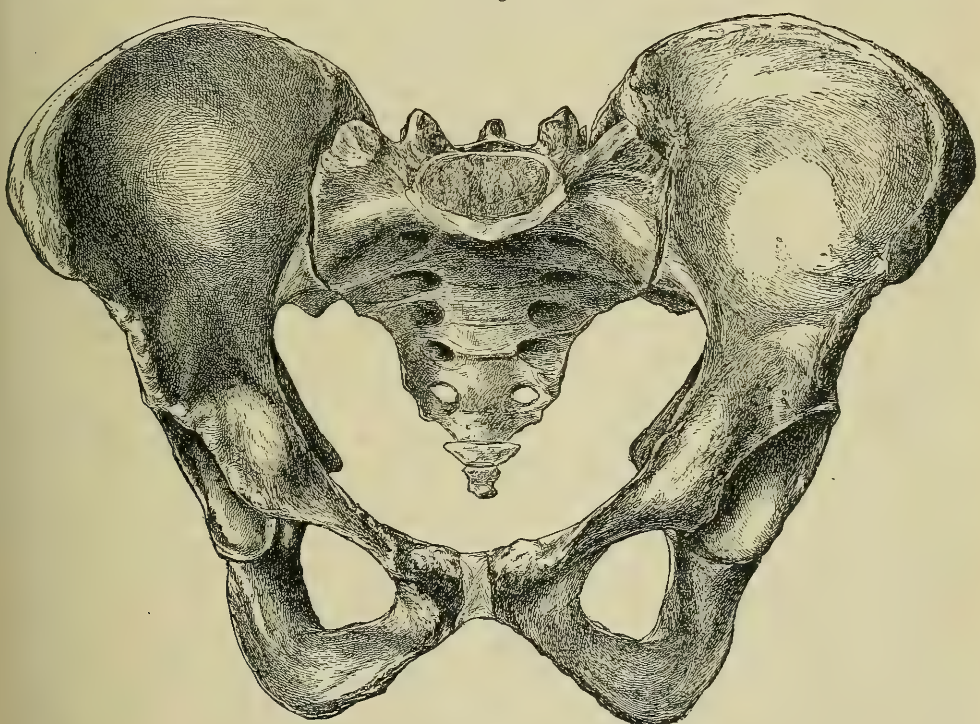
DIAMETERS OF THE TRUE PELVIS.

	Male.			Female.		
	Inlet. Cm. (Inches).	Cavity. Cm. (Inches).	Outlet. Cm. (Inches).	Inlet. Cm. (Inches).	Cavity. Cm. (Inches).	Outlet. Cm. (Inches).
Antero-posterior	10.25 (4)	11.5 (4½)	8.25 (3¼)	10.25 (4)	12.75 (5)	11.5 (4½)
Transverse . . .	12.75 (5)	12.0 (4¾)	9.00 (3½)	13.25 (5¼)	12.75 (5)	12.0 (4¾)
Oblique	12.00 (4¾)	11.5 (4½)	10.25 (4)	12.75 (5)	13.25 (5¼)	11.5 (4½)

The **index of the pelvis,** of interest in anthropology, is the proportion of the antero-posterior diameter to the transverse at the pelvic inlet, the latter being 100. This index is 80 for European males and 78 for females (Verneau). In the lower races it is considerably higher, implying a narrower pelvis. Pelves with indices below 90 are *platypellic*, with indices from 90 to 95 *mesatipellic*, and above 95 *dolichopellic*.

Another index to show the relative depth of the pelvis is the proportion of the breadth between the most distant points of the iliac crests to the height from the top of the crest to the tuberosity of the ischium, the latter being 100. According to

FIG. 366.



Female pelvis from before.

Topinard, this index is 126.6 for male and 136.9 for female Europeans. It is lower in the lower races, showing that in them the pelvis is relatively deeper.

Differences due to Sex.—The sexual differences of the pelvis are far more marked than those of any other part of the skeleton. The male pelvis is deeper and narrower, the female shorter and broader. It is to be noted that the greater breadth of the female applies essentially to the true pelvis. At the inlet this is both relatively and absolutely broader in woman. The male promontory is more projecting. The most characteristic feature is the pubic arch, which is of a much greater angle in woman. According to Verneau, it is from 38° to 77° in the male, with an average of 60°; and from 56° to 104° in the female, with an average of 74°. The symphysis is shorter in woman, and the borders of the arch probably more everted. The

greater lightness of the female skeleton shows particularly in this part of the pelvis. It is owing to the greater divergence of the rami that the front of the obturator foramen is straighter in the female, making it more triangular and less oval than in the male. The spines of the ischia are farther apart in woman. According to Verneau,[1] those in man are rarely more than 10.7 centimetres (4¼ inches) apart, and often less than 9 centimetres (3½ inches); while in woman they are often more than 10.7 centimetres apart, and never less than 9 centimetres. He states also that in man the spines of the ischia are sometimes internal to the posterior inferior spines of the ilia, but that they are always external to them in woman. The sacro-sciatic notch is usually wider and less deep in the female. There is much irregularity in regard to the false pelvis. The anterior superior spines of the ilia are farther apart in woman. It does not follow that the same is true of the most lateral points of the crests of the ilia. In powerful male bodies they are farther apart than in female ones. The vertical depth of the false as well as of the true pelvis is greater in the male. As has been stated elsewhere, the male sacrum is the more regularly curved.

Development.—The pelvis of the fœtus and infant is strikingly small, and continues relatively so for some years. The peculiarity of its shape is largely due to the sacrum. Even at birth there is but a very rudimentary promontory, and the sacrum is straight or nearly so. Consequently the pelvis is funnel-shaped, being largest above. The height is greater in proportion to the breadth than later. It has been shown by Fehling[2] and Thompson[3] that the sex of the pelvis may be recognized by the usual signs as early as the fourth month of fœtal life. In the fœtus the transverse diameter of the inlet exceeds the conjugate, especially in the female. The average subpubic angle of the fœtus is 50° in males and about 68° in females. In the latter the ischial spines are farther apart and the sacro-sciatic notches wider. Although after birth the promontory becomes stronger, it has a tendency to be double partly above and partly below the first sacral. This is corrected at a very indefinite time in early childhood. Of the details of the changes by which the great difference between the sexes is brought about we know very little. Waldeyer[4] states that the external measurements of the female pelvis surpass those of the male from the eleventh to the fifteenth year, but particularly from the fourteenth to the sixteenth. The growth of the male pelvis is more regular.

Mechanics of the Pelvis.—The mechanical function of the human pelvis, apart from protecting the viscera, is chiefly to support the spine, whether sitting or standing. The interruptions of the bony girdle at the symphysis and the sacro-iliac joints add to the strength of the structure and break shocks. There is, however, a real motion at the sacro-iliac joints which, slight under ordinary circumstances, is of importance in childbirth. The weight of the body transmitted through the spine may theoretically be said to tend to force the sacrum down between the innominate bones and also to carry the promontory downward and forward into the pelvis, the sacrum rotating on a transverse axis passing through the second piece at the sacral canal. Motion in the former direction does not occur, but in the latter it may to a slight degree.[5] With the body lying on the back, if the legs are strongly flexed and pressed against the abdomen, the pelvis rotates on the sacrum, the symphysis rises, and the antero-posterior diameter of the inlet is lessened; if the legs be strongly extended by being brought down over the edge of the table, this diameter is increased, the difference between the extremes being one centimetre. At the end of pregnancy these joints, as well as that of the symphysis, are loosened so as to admit of more motion, which is no doubt of real value. Assuming, as at first, the pelvis to be the fixed part, the tendency to displacement of the sacrum in either of these directions is resisted by the posterior sacro-iliac ligaments. The sacrum is not really a keystone, for the anterior surface is broader than the posterior, except in some few sections.

[1] Le bassin dans les sexes et dans les race, Paris, 1870.
[2] Arch. für Gynäkol., Bd. x., 1876.
[3] Journal of Anatomy and Physiology, vol. xxxiii., 1899.
[4] Das Becken, Bonn, 1899.
[5] G. Klein: Zeitschrift für Geburtshülfe und Gynäkol., Bd. xxi., 1891.

The weight in standing is transmitted to the thigh bones, in sitting to the tuberosities of the ischia ; in both cases the parts of the pelvis running to the pubes act as "ties" to prevent the spreading of the arch. The circumference of the acetabulum is of strong bone to resist pressure from the joint, and in the erect position a strong part runs from the socket directly upward to the crest of the ilium. The thinness of the bottom of the acetabulum in all ages and the meeting there in childhood of the three bones make it a weak place.

Surface Anatomy.—The anterior superior spine of the ilium is easily felt, but care must be taken not to mistake for it a swelling of the crest an inch or more behind it. To make sure of this spine as a point for measurements, the finger should be carried over it from the crest and then back again till it is arrested by the overhanging spine. The anterior inferior spine cannot be felt. The outer lip of the crest of the ilium can easily be followed to the posterior superior spine, which is marked by a dimple, and is on a level with the middle of the sacro-sciatic joint. The tuberosity of the ischium is readily felt, but it is too thickly covered for details to be recognized. A line drawn from the posterior superior spine to the outer part of the tuberosity of the ischium will cross the inferior spine of the ilium and the spine of the ischium. A line from the same point to the top of the greater trochanter will pass very close to the highest point of the great sacro-sciatic notch. The symphysis of the pubes and most of the borders of the pubic arch can be felt. The spine of the pubes can be recognized, but usually not without some difficulty. It may be necessary to feel for it beneath the skin by invaginating the scrotum or labium. In woman it is nearly 2.5 centimetres from the median line ; in man somewhat less.

PRACTICAL CONSIDERATIONS.

Failure of development in the separate bones of the pelvis produces certain well-known deformities. In the sacrum, the arch of the upper sacral vertebra, which is formed later than the others and varies notably in thickness, is frequently incomplete, which results in the very common occurrence of *spina bifida* at this region (page 1051).

When the pelvic girdle is incomplete anteriorly, there is an interval of several inches between the pubic bones, and all the bones of the pelvis are changed somewhat in shape and direction. The defect may be associated with exstrophy of the bladder, epispadias in the male, split clitoris in the female, double inguinal hernia, ectopia of the testicles, and sometimes ventral hernia from separation of the recti muscles.

Deformities of the pelvis have even more interest to the obstetrician than to the surgeon. The usual differences between the male and female pelves are sometimes absent, constituting an abnormality, though perhaps stopping short of actual deformity. The so-called *masculine* pelvis, for example, is characterized by a diminution in the breadth of the pubic arch and an increase in the pubic angle.

The female pelvis, as compared with that of the male, is lighter, less compact, more expanded, shorter in vertical depth, broader at the inlet, with a greater angle in its pubic arch, a lesser curve in the sacrum, and a greater separation between the ischial spines, and is thus more perfectly adapted to the purposes of parturition.

The chief deformities due to faulty development may be at least enumerated here on account of their importance in this relation. In the *simple flat pelvis* the antero-posterior diameter is contracted by the advancement of the sacrum in a downward and forward direction between the iliac bones. The *equally contracted pelvis* resembles a miniature normal female pelvis with other peculiarities that approximate it to the infantile type. The *funnel-shaped pelvis* is contracted transversely at the outlet in both the antero-posterior and transverse diameters, the cavity is deeper, the sacrum is narrow and less curved. These peculiarities are found in very early life, and hence this is also known as the *fœtal pelvis*. The *obliquely contracted pelvis* is due to imperfect development of the ala on one side of the sacrum, which is associated with many secondary deformities, among them a lack of curvature of the innominate bone on the affected side. The *transversely contracted pelvis* in which both sacral alæ are undeveloped is rarest of all contracted pelves. The

functional importance of these pelvic contractions should be studied in connection with the mechanism of labor.

The pelvis may be deformed as a result of morbid conditions in other parts of the skeleton. A lateral curvature of the lumbar spine to the left may thus be accompanied not only by the usual compensatory dorsal curve to the right, but by a curve in the latter direction in the sacrum, the upper margin of which will be higher on the right side than on the left. Even the corresponding rotation will take place, and the ala on the concave side will be rotated forward, as are the transverse processes of the dorsal vertebræ.

Irregularity in the lengths of the lower limbs may produce a similar curve in the sacrum.

In both cases the whole pelvis will be tilted laterally, the iliac crest being higher on the convex side of the sacrum. It has been suggested that this continuation of a spinal curvature into the sacrum is sometimes a cause, and not a result, of the obliquely contracted pelvis described above, with which it is often associated, but which is regarded as congenital in its origin.

Humphry, after describing the ring of the pelvis as heart-shaped, and calling attention to the wide arch with a flattened or depressed centre of the upper or posterior half, and the greater curve with flattening at the ilio-pectineal regions of the lower or anterior half, says, "It results from this configuration of the pelvic ring that it is weakest at five points,—viz., at or a little external to both sacro-iliac synchondroses, at the symphysis pubis, and midway between the latter and the acetabula. Hence fractures, whether from falls, blows, or foreign bodies passing over the pelvis, are most frequent at these points."

In studying the clinical effects of traumatism applied to the pelvis, it is helpful, however, to consider it with reference to its various functions,—*i.e.*, (*a*) as interposed between the vertebral column and the lower extremities as a weight-carrier; (*b*) as a means of providing for the motions of the trunk upon the lower limbs and of affording advantageous points of attachment for the muscles which effect that motion; (*c*) as a bony protection or receptacle for the abdominal and pelvic viscera.

1. If it is viewed as a bony ring between the spine and the thigh bones, intended to transmit the weight of the head and trunk from the former to the latter, the pelvis may be regarded as made up of two main arches,—one which is in use when standing, the other when sitting. The sacrum is the point of union of both these arches,—one, the femoro-sacral (Morris), extending from the acetabulum through the strong thickened mass of bone indicated on the inner surface by the upper third of the ilio-pectineal line to the sacrum through the sacro-iliac joint; the other, the ischio-sacral, extending from the tuber ischii through the strong bony mass at the posterior edge of the acetabulum to the same point. These are the essential weight-carrying portions of the pelvis.

Although Cunningham says that, as the sacrum narrows towards its dorsal surface, and is really suspended from the iliac bones by the posterior sacro-iliac ligaments, it cannot be considered as the keystone of an arch, yet the union between the sacrum and the ilia is so close by virtue of these powerful ligaments, of those upon the anterior aspect, and of the reciprocal irregularities of the sacro-iliac articular surfaces, that the objection, though technically correct, is clinically a theoretical one only. In describing the mechanics of the remaining or accessory portions of the pelvis, regarded as a weight-carrier, Morris calls attention to the fact that when much strength is essential in an arch, it is often prolonged into a ring so as to form a counterarch,—*i.e.*, the ends of the arch are tied together to prevent them from starting outward. A portion of any weight to be carried by the arch is thus conveyed to the centre of the counterarch, and borne in what is called the sine of the arch. In the pelvis "the body and horizontal rami of the pubes form the tie or counterarch of the femoro-sacral, and the united rami of the pubes and ischium the tie of the ischio-sacral arch." The ties of both arches are united in front at the symphysis pubis, which, like the sacrum, is common to both arches.

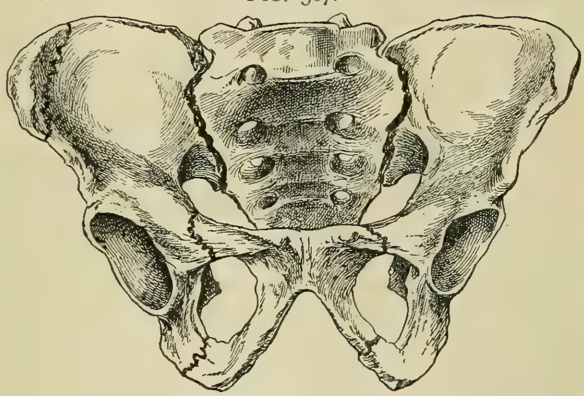
It can now be understood how and why a fall upon the feet, or a crush either antero-posterior or lateral in direction, though such dissimilar accidents, are so apt to

produce fracture of the horizontal or the descending ramus of the pubes, the ramus of the ischium, or of the ilia external to the sacro-iliac junction.

If the accident has been a fall upon the feet, the injury will probably be confined to the acetabulum or to the pubes. In young subjects the acetabulum may be separated into its three anatomical components (Fig. 355), or a portion of the rim may be broken off, or in rare cases the head of the femur may be driven through into the pelvic cavity.

If the traumatism has been a crush in the antero-posterior direction, the pubes will probably first fracture; if the force is continued, the protection afforded by the "tie arch" having been withdrawn, the pressure comes upon the main arches, which tend to open out. A portion of one of these arches may then give way, and a second fracture may occur through the ilium into the sacro-sciatic notch, or vertically through the sacrum itself. More commonly, however, the anterior sacro-sciatic ligaments give way and a certain amount of disjunction of that joint occurs. Even if the crushing force is applied laterally, it is usual to find the pubes again fractured from indirect violence. If the application of the force is continued, the strain comes upon the posterior sacro-iliac ligaments, which may rupture, but are more likely to withstand the violence, which then may result in the tearing away of a portion of the bone into which the ligament is inserted.

Fig. 367.



Lines of fractures of the pelvis.

The pubic fracture is discoverable by the usual means. The vertical fracture of the ilium or the disjunction of the sacro-iliac synchondrosis anteriorly should be suspected if there is pain in the region supplied by the superior gluteal, the lumbo-sacral, the upper sacral nerves, or the obturator,—*i.e.*, in the sacral region, the buttock, the back or inner part of the thigh, or the knee,—on account of the relation of these nerves to the anterior surface of the joint.

Marked ecchymosis, swelling, and tenderness over the sacro-iliac regions posteriorly indicate tearing of the posterior ligaments or the fracture by *arrachement* that has been described.

In all these cases the gravity of the injury depends upon the presence or absence of visceral complications. If a double vertical fracture exists, extending through the rami of the pubes and ischium in front and through the ilium near the sacro-iliac junction posteriorly, it is obvious that there will be one large fragment of the pelvis more or less movable, to which the femur on that side is connected. This condition may be associated with upward displacement of the fragment, carrying the femur with it, and it may give rise to a mistaken diagnosis of fracture of the neck of the femur. It should be remembered, as Tillaux has pointed out, that in the pelvic lesion the relation of the greater trochanter to the anterior superior iliac spine is normal, and the real length of the limb on the affected side is the same as that on the sound side.

2. Other fractures, as those through the lateral expansions of the ilia, and epiphyseal separations involving the pelvis, have relation more especially to its function as affording a means of moving the trunk upon the lower limbs. The epiphyses chiefly separated are those of (*a*) the iliac crest, (*b*) the anterior superior spine, (*c*) the posterior superior spine, and (*d*) the anterior inferior spine.

The first three of these are often united in one long epiphysis, but portions of this may be detached separately by muscular action or by direct violence. Cases of separation of the anterior superior spine by the action of the abdominal muscles and by that of the sartorius have been reported.

The anterior inferior spine, which is peculiar to the human pelvis, and affords a slight leverage which partly enables the rectus femoris to overcome the disadvantage of the erect position, has been torn off in the act of running.

Although the ischial tuberosities are subjected to enormous pull from the powerful hamstring muscles, as in the act of suddenly straightening the trunk from a bending position (when these bones project far behind the axial plane and thus offer better leverage), their epiphyseal disjunction or their fracture from muscular action is practically unknown. From direct violence both of these lesions occur, but with great rarity.

3. Considered in relation to the abdominal and thoracic viscera, the injuries and diseases of the bones of the pelvis are of great importance. Fractures of the false pelvis have been followed by fatal wound of the small intestine. Fractures running through the brim of the pelvis have been associated with hemorrhage from the iliac vessels; fractures of the pubis and ischium have constantly been complicated by wounds of the urethra and bladder, and even of the rectum. The possibility of these complications should never be forgotten. The obvious anatomical reasons for their occurrence will be recurred to when these viscera are described.

Disease of the pelvic bones, like their deformities, is of chief importance in its relation to parturition.

In *rickets* the shape of the pelvis is modified through the medium of the superimposed weight of the trunk and through the pull of muscles resisted by the interosseous ligaments.

The weight of the body, aided by the psoas muscles, tends to press the sacrum downward and forward between the iliac bones and to rotate the upper end forward on a transverse axis. The sacro-sciatic and sacro-iliac ligaments resist this force, which thus results in thrusting the promontory of the sacrum towards the pubes and in increasing the sacro-vertebral angle, or making a sharp bend in it, often at the junction of the fourth and fifth sacral vertebræ. The sacro-iliac ligaments convey this movement to the posterior superior spinous processes, which, advancing somewhat forward and inward, would tend to throw the anterior half of the innominate bones outward. These are held, however, firmly at the symphysis and—much less effectively—by Poupart's ligament. The ilia are thus thrown outward and backward, so that the distance between their spines may be equal to or greater than that between the summits of the crests. As a further result of these combined forces pushing the innominate bones forward from behind and holding them in place in front, they are abnormally curved, as a bow is bent between one's hand and the ground (Hirst). This bending of the ilia, together with the pull of the external rotators of the thigh (increased by the usual bowing of the femurs), carries the tuberosities of the ischium outward, so that they diverge like a monkey's, flattening and widening the pubic arch and increasing the transverse diameter. The weight of the trunk on the summit of the sacrum is so much the most effective and continuous force applied as the growing child walks or stands that the whole pelvis is tilted forward on its transverse axis, the inclination of the superior strait being increased and the external genitals displaced backward.

In *osteomalacia* the bones are much softer than in rickets and the mechanism of the pelvic deformity is simpler. The sacrum yields under the pressure of the body weight, and becomes acutely angulated and driven forward and downward into the pelvis; the ischia and pubes are pushed inward and backward by the force transmitted through the acetabula, the pubic angle is greatly increased, and the pelvis assumes an irregularly triangular or "triradiate" shape.

The rhachitic and osteomalacic pelves may approximate each other in shape, but are usually distinct.

Exostoses of the pelvis are usually found over one of the joints, or at points of muscular or fascial attachment, as along the pubic crests where the iliac fascia is inserted.

Enchondroma is relatively common in the pelvis, and other growths occasionally originate there.

Congenital tumors are often found in the sacro-coccygeal region. Their shape

sometimes resembles the tail of lower animals. They frequently arise from the anterior part of the coccyx behind the rectum, and contain muscular, bony, epithelial, or cartilaginous elements in an imperfect and fragmentary condition. When a third lower limb is found connected with this part of the pelvis, the condition is known as "tripodism."

In some of the reported cases of parasitic fœtuses the point of junction has been in this region.

Sinuses over the sacrum and coccyx occasionally persist after abscesses following blows or falls. If the pus has travelled in a lateral direction, the suppurating track will be found to lead to the region of origin of the tendinous sacral and coccygeal fibres of the gluteus maximus. The probe may catch against these points and give a kind of grating sound, like that due to bare or dead bone. The continuance of the sinuses is not the result of necrosis, but is due to the unyielding character of the tendinous structures. This prevents apposition and union of the sinus walls until tension has been removed.

Landmarks.—Anteriorly, the anterior superior spinous process of the ilium is most easily recognized as a prominence at the outer end of the fold of the groin. In very fat subjects its situation is indicated by an oblique, slightly elongated depression. It is a little above the level of the promontory of the sacrum. Running upward and outward and curving backward in an irregularly S-shaped line is the iliac crest. In muscular subjects the fibres of the external oblique overhang the crest, causing a crease in the soft parts which lie between these fibres and those of the gluteus medius a little below the level of the crest; it is known as the "iliac furrow." It is less marked where the crest passes below the tendinous portion of the erector spinæ.

Fig. 368.

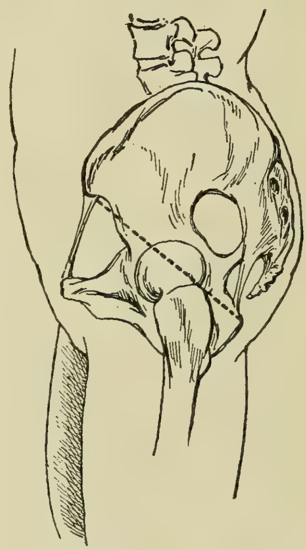


Diagram showing Nélaton's line.

The posterior superior spine is not so prominent as the anterior, but may easily be found by following the crest to its posterior termination. Its position is indicated by a slight depression on the surface on a level with the second sacral spine and behind the middle of the sacro-iliac joint. The third sacral spine lies just below in the mid-line, and indicates the level to which the membranes of the cord enclose a distinct space, and, therefore, the lowest point at which cerebro-spinal fluid can be found. The curve of the sacrum and coccyx may be traced to the tip of the latter.

The ischial tuberosities are easily felt when the hip is flexed and the fibres of the gluteus maximus are thus withdrawn. A bursa is interposed between them and the layer of subcutaneous fat which covers them. They can be felt, but with more difficulty, through the gluteus fibres when the hip is in extension. Five centimetres (two inches) below the posterior superior spine, on a line drawn from it to the outer part of the tuberosity, lies the posterior inferior spine, and five centimetres (two inches) lower still the spine of the ischium. The sciatic and internal pubic arteries emerge at the junction of the lower and middle thirds of this line. The pudic artery crosses the spine of the ischium on its way between the great and small sacro-sciatic foramina. A line, called Nélaton's, drawn from the anterior superior spine to the prominence of the tuber touches the top of the greater trochanter and crosses the centre of the acetabulum (Fig. 368).

The pubic symphysis may be felt indistinctly and the horizontal rami more easily.

The pubic spine is readily felt in thin persons. In fat males it may be most easily found by invaginating the scrotum. In either sex the tendon of the adductor longus—made tense by abducting the thigh—is an unfailing guide to it. It lies on the level of the upper edge of the greater trochanter. It is just below and a little

internal to the external abdominal ring, and is on the outer side of an inguinal hernia and on the inner side of a femoral hernia.

With the finger in the rectum, the tip of the coccyx and a little of the anterior curve can be felt, as well as the small sacro-sciatic ligaments leading to the ischial spines. Laterally, the tuberosities of the ischium, the smooth bone forming the wall of the pelvis, and the structures back of the acetabulum (page 1693) can be palpated.

Through the vagina the configuration of the subpubic arch can be felt, also the pelvic wall to either side. If the promontory of the sacrum can be touched, it indicates deformity accompanied by diminution of the antero-posterior pelvic diameter.

With the hand in the rectum, the brim of the pelvis, the arch of the pubes, the sacral promontory, the curve of the sacrum and coccyx, the spines of the ischium, and the margins of the sacro-ischiatic foramina can be palpated.

The Joints of the Pelvis.—The *sacro-lumbar joint* has a wider range of movement than any of the joints between the contiguous dorsal or lumbar vertebræ. This is due to the greater thickness of the intervertebral substance, permitting flexion and extension, and to the fact that the inferior articulating processes point more antero-posteriorly than those of the other lumbar vertebræ, thus admitting of more rotation on a vertical axis.

In spite of this, on account of the strength of the ligaments of the joint, and more particularly for the reasons that tend to localize the effect of traumatism somewhat higher in the spine (page 145), sprain and disease of the sacro-lumbar articulation are both uncommon.

Overextension of the joint is brought about if with the body prone the shoulders are raised while the hips are fixed. Pain thus produced suggests lumbar or sacro-lumbar disease, as in sacro-iliac disease this movement is often painless.

The *sacro-coccygeal joint* is not infrequently strained by falls upon the buttocks, and occasionally the coccyx is displaced forward. The joint is sometimes the subject of disease. The symptoms are very similar in all these conditions. The attachment of the gluteus maximus makes a change from a sitting to a standing posture or the reverse movement painful ; it also causes pain if long steps are taken or if running is attempted, and this is aggravated by the action of the hamstring muscles through the medium of the great sacro-sciatic ligament. As the fixed point of the external sphincter is at the tip of the coccyx, and as the levator ani is inserted into the sides of the tip, defecation is associated with movement in this joint, and therefore with pain. The latter is often disproportionate to the apparent severity of the injury or disease, and there may be also great tenderness to the touch posteriorly, with no swelling or local heat. As these cases chiefly occur in women, Hilton thinks that they are truly "hysterical," and calls attention to the intimate structural communication between the many sacral nerves spread over the posterior surface of the sacrum and coccyx and the anterior sacral nerves, which join with the hypogastric plexus of the sympathetic within the pelvis and thence proceed to the uterus and ovaries.

The motion of the sacro-coccygeal joint is of great importance in its relation to obstetrics. Ankylosis occurs, as a rule, between the thirtieth and fortieth years, but the joint between the first and second sacral vertebræ usually remains unaffected, and leaves the capacity for antero-posterior expansion during labor practically unimpaired.

The Sacro-Iliac Joint.—Injury to and disjunction of this joint have been sufficiently described under Fractures of the Pelvis (page 347).

Disease of the joint, on account of its strength and immobility, is rare. It is usually tuberculous in character, and is often secondary to suppuration beneath the ilio-psoas from disease of the spine, ilium, or hip. Pain is felt on standing, walking, or sitting, as the sacrum in all these positions bears the weight of all the superincumbent structures, and on account of its shape (page 346) transmits it to the sacro-iliac synchondrosis. The pain is increased by coughing, straining, or twisting the loins,—*i.e.*, by whatever calls into action the muscles attached to the ilium. Through the relation of the superior gluteal nerve to the front of this joint, pain is often felt in the buttock, and there is wasting of the deep gluteal muscles. The

relation of the lumbo-sacral cord, the upper sacral nerves, and the obturator has already been mentioned (page 347).

The body is inclined to the sound side, so that when sitting the pressure on the diseased structures may be lessened, and when standing separation of the joint surfaces may be secured by the weight of the lower limb. The length of the latter is apparently increased on account of a downward rotation of the innominate bone on the affected side, but measurements from the anterior spines to the malleoli will be the same. Tenderness on direct pressure may be elicited just below the posterior iliac spine; on indirect pressure by squeezing the ilia together or by separating them so as to put the anterior ligaments on the stretch.

Pus may find its way backward and appear at or near the joint line. It more often passes forward on account of the greater thinness of the anterior ligament. It may then enter the sheath of the ilio-psoas and be conducted to the anterior surface of the thigh; it may follow the obturator vessels through the obturator canal and point on the inner aspect of the thigh; it may be guided by the sciatic nerve and the lumbo-sacral cord to the region behind the greater trochanter; it may descend between the obturator fascia and the anal fascia into the ischio-rectal fossa and appear at the side of the anus; or, finally, it may ulcerate into the rectum and be discharged per anum.

The *symphysis pubis*, as the centre of the counterarch of the pelvis (page 346), is subject to manifold strains and injuries; but, as the union between the two innominate bones at that point is really by a strong, solid, fibro-cartilaginous band, and is without a synovial cavity, and as it is greatly strengthened by the decussation of the fibres of the anterior and inferior ligaments, its separation by traumatism is very rare, and is in effect a fracture.

The anterior ligament is much stronger than the posterior to resist the downward and forward pull of the adductors and the weight of the abdominal walls and viscera. Its strength accounts for the fact that fracture of the horizontal rami is more common than disjunction of the symphysis in cases in which compressing force has been applied to the pelvis laterally.

In cases of disease when the bond of union is weakened, the function of the counterarch readily explains the weakness and powerlessness in standing or sitting.

The symphysis is of great importance in its relation to obstetric mechanics and measurements. The plane of greatest pelvic expansion extends from the junction of the second and third sacral vertebræ posteriorly to the middle of the symphysis; the plane of least pelvic diameter from the sacro-coccygeal articulation to the lower third of the symphysis.

There is thought to be a trifling separation of the symphysis during pregnancy and labor, but this is counteracted by the decussation of the aponeurotic fibres of the oblique muscles at the linea alba. On account of this decussation these muscles tend, when in vigorous action, as in parturition, to draw the pubic bones together.

The symphysis, however, although comparatively unyielding, is in almost the same horizontal plane with the coccyx, the most movable bone that enters into the formation of the pelvis, and with the obturator foramina and the lower part of the great sacro-sciatic foramina. This is in accord with the fact that in no horizontal plane does the pelvis form a complete bony and unyielding ring, but everywhere the resisting bony portion has opposite to it one or more soft and yielding segments, as, for example, the hypogastric region of the abdomen is opposite the fixed and immovable sacrum (Morris).

In obstructed labor in which the delivery of a living child may be made possible by a moderate increase in the pelvic outlet, the operation of *symphysiotomy* is often performed. The aponeurosis of the recti is incised, the retro-pubic structures separated by a finger, and a probe-pointed bistoury passed down and made to cut forward and upward. The incision may with advantage be made in the reverse direction, as the symphysis is wider at its upper than at its lower margin, and is wider anteriorly than posteriorly. The subpubic ligament and the deep perineal fascia should then be detached from the pubic arch close to the bone, so as to avoid tearing the structures that penetrate the fascia—the vagina, the urethra, the dorsal vein of the clitoris, and other venous channels—when the pubes are separated.

The motion which permits of separation takes place in the sacro-iliac joints, and the pubic bones move downward as well as outward, adding materially to the amount of pelvic space gained. With a separation of seven centimetres (two and three-fourths inches), which is possible under gentle pressure without laceration of the sacro-iliac ligaments, the gain in the conjugate diameter is 1.5 centimetres (three-fifths of an inch). The projection of the anterior parietal boss into the pubic interspace as the bones recede from each other adds to the space gained, so that by opening the pubic joint to the extent of 6.5 centimetres (two and three-fifths inches) the increase in the conjugate diameter amounts in effect to about two centimetres (three-fourths of an inch) (Cameron).

THE FEMUR.

The femur, a typical long bone, has a *shaft* and two *extremities*. The lower end rests on the tibia, pretty nearly in a horizontal plane; from this the shaft slants outward, forming an angle of about 10° with a vertical line.

The **upper extremity** consists of a *head*, a *neck*, and *two trochanters*. These last are on the shaft at the junction with the neck, which runs upward and inward, forming with it an angle of about 125° on the average.

The **head** is a rounded swelling, representing rather more than half a sphere, capping the end of the neck. It is not put on symmetrically, but covers more of the upper side of the neck than of the lower, and probably, as a rule, more of the front than of the back. Occasionally it is prolonged onto the upper anterior aspect of the neck. It is smooth and covered with articular cartilage except at a *depression* for the ligamentum teres, below and posterior to the axis of the head. Brockway,[1] having examined 300 femurs, found this depression oval in 43 per cent., with the long axis running downward and somewhat backward, triangular in 35 per cent., and circular in 22 per cent. In 84 per cent. he found vascular foramina, which are larger in the young and not necessarily pervious in the old. In a few cases he found a persistence of the fœtal condition,—namely, a groove descending nearly to the border of the articular surface.

The **neck**[4] extends upward and inward, and usually forward. Being compressed from before backward, it has a front and a back surface with thick upper and lower borders. The lower rises more steeply from the shaft than the upper, so that the neck is much broader at the base than where it joins the head. The lower border is the longer, and the posterior surface is longer than the anterior. The neck is smooth below and behind, rather rough in front and above. The upper border has numerous nutrient foramina. The lower border, springing from the inner aspect of the shaft, often presents a rounded ridge running to the lesser trochanter. The neck is bounded behind by an elevation connecting the trochanters, the *posterior intertrochanteric ridge*.[5] The *spiral line*,[6] also called the *anterior intertrochanteric ridge*, bounds the greater part of the front. It starts at the little *superior cervical tubercle*, at the junction of the top of the neck with the greater trochanter, runs downward and inward to the level of the lesser trochanter, where it sometimes presents a smaller *inferior cervical tubercle*, and then, descending more rapidly, twists round the shaft to join the inner lip of the linea aspera. Thus a small part of the neck between this line and the lesser trochanter has no boundary. We have found the average length of the neck on thirty-eight male bones and twenty-six female ones respectively 4.3 centimetres and 4 centimetres. Bertaux gives 46.6 millimetres and 43.1 millimetres respectively.

The **greater trochanter**[7] is a large process projecting upward and outward from the top of the shaft and turning inward to overhang the back of the neck. Seen from the outside its outline is roughly square, but the upper border generally rises towards the back so as to form a point. The anterior surface presents a *depressed area* for the insertion of the gluteus minimus. The outer side is crossed by a *ridge* running downward and forward, to and in front of which is attached the gluteus medius. The *upper border* receives at the front end the tendons of the obturator internus and gemelli, and a little farther back that of the pyriformis. The hollow

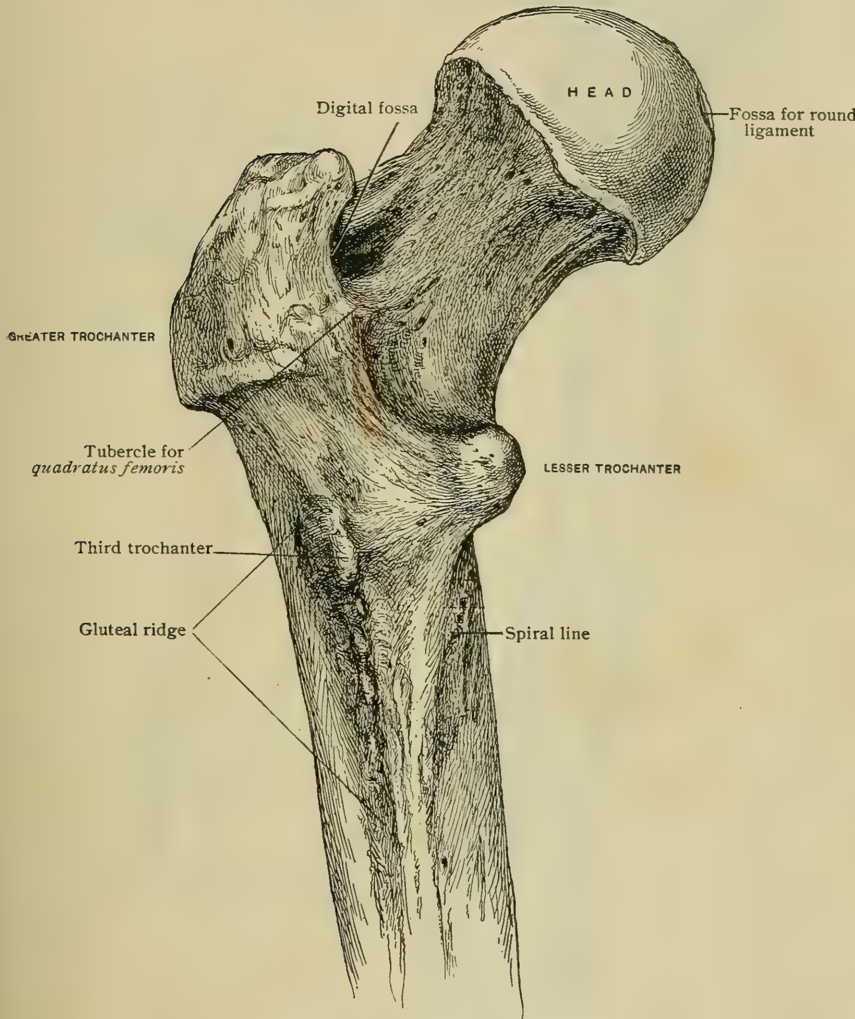
[3] Proceedings of the Association of American Anatomists, 1896.

[1] Caput femoris. [2] Fovea capitis femoris. [4] Collum femoris. [5] Crista intertrochanterica. [6] Linea intertrochanterica. [7] Trochanter major.

between the neck and the overhanging trochanter is the *trochanteric* or *digital fossa.*[1] There is usually a round recess at its anterior end for the tendon of the obturator externus.

The **lesser trochanter**[2] is a rounded knob at the inner side of the posterior aspect of the shaft at its junction with the neck. The posterior side is triangular. It is at the junction of three lines : the *posterior intertrochanteric ridge*, a line running down to the linea aspera, and an inconstant ridge on the neck. It receives on its end the tendon of the ilio-psoas, and below some of the iliac fibres of that muscle

FIG. 369.



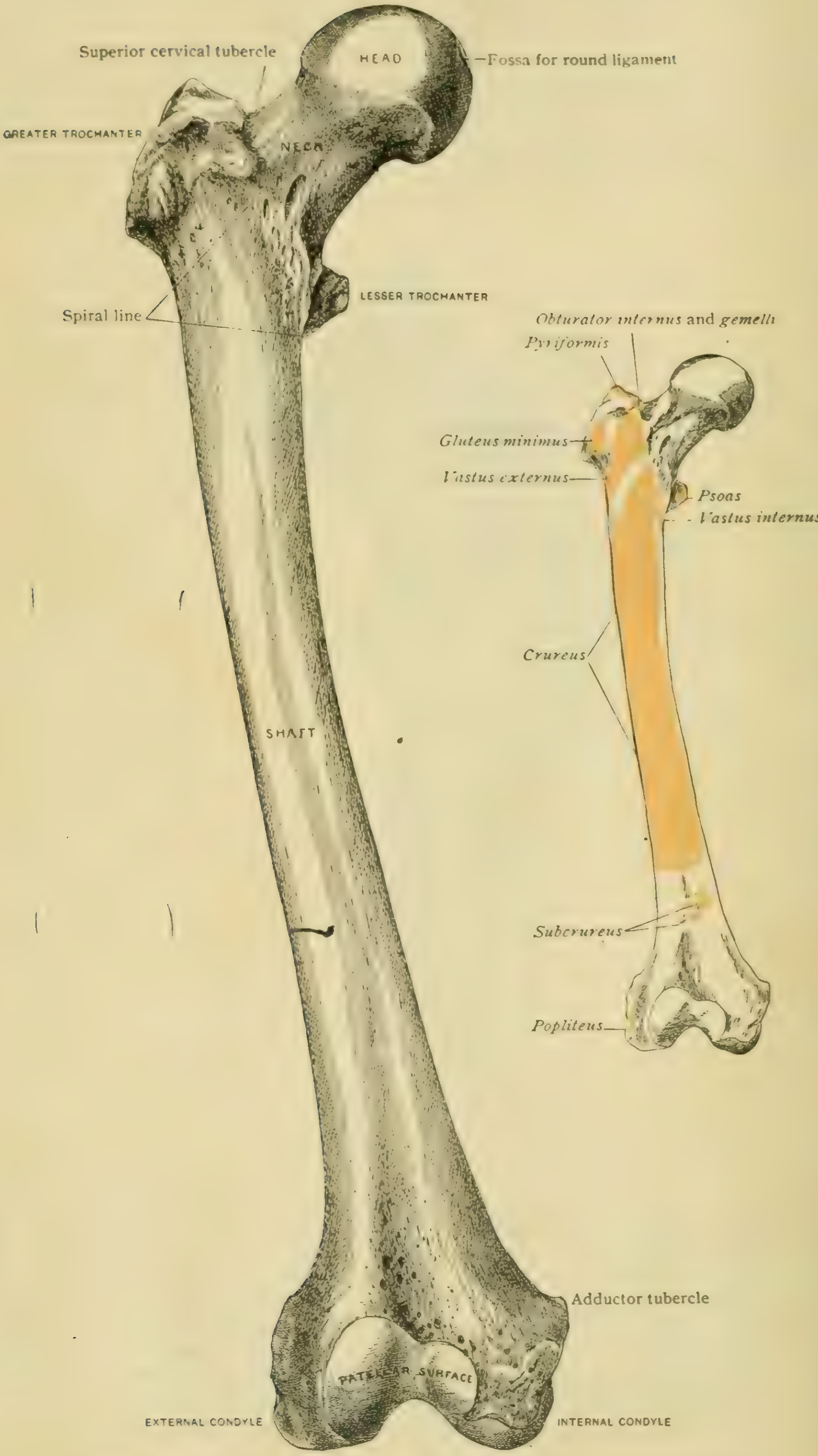
Upper extremity of left femur from behind.

That part of the **spiral line** above the level of the lesser trochanter (the so-called anterior intertrochanteric ridge) is generally a very distinct rough line. It may be so faint as to be hardly distinguishable, and extremely rarely a hollow may be found in its place. The **posterior intertrochanteric ridge** is a thick swelling, broader above than below. Near its junction with the greater trochanter it has a slightly rounded prominence, or occasionally a vertical line, *linea quadrati*, for the quadratus femoris.

The **shaft**[3] is very strong, and convex in front, except below the neck, where it is slightly concave. In the middle it would be nearly cylindrical were it not for the

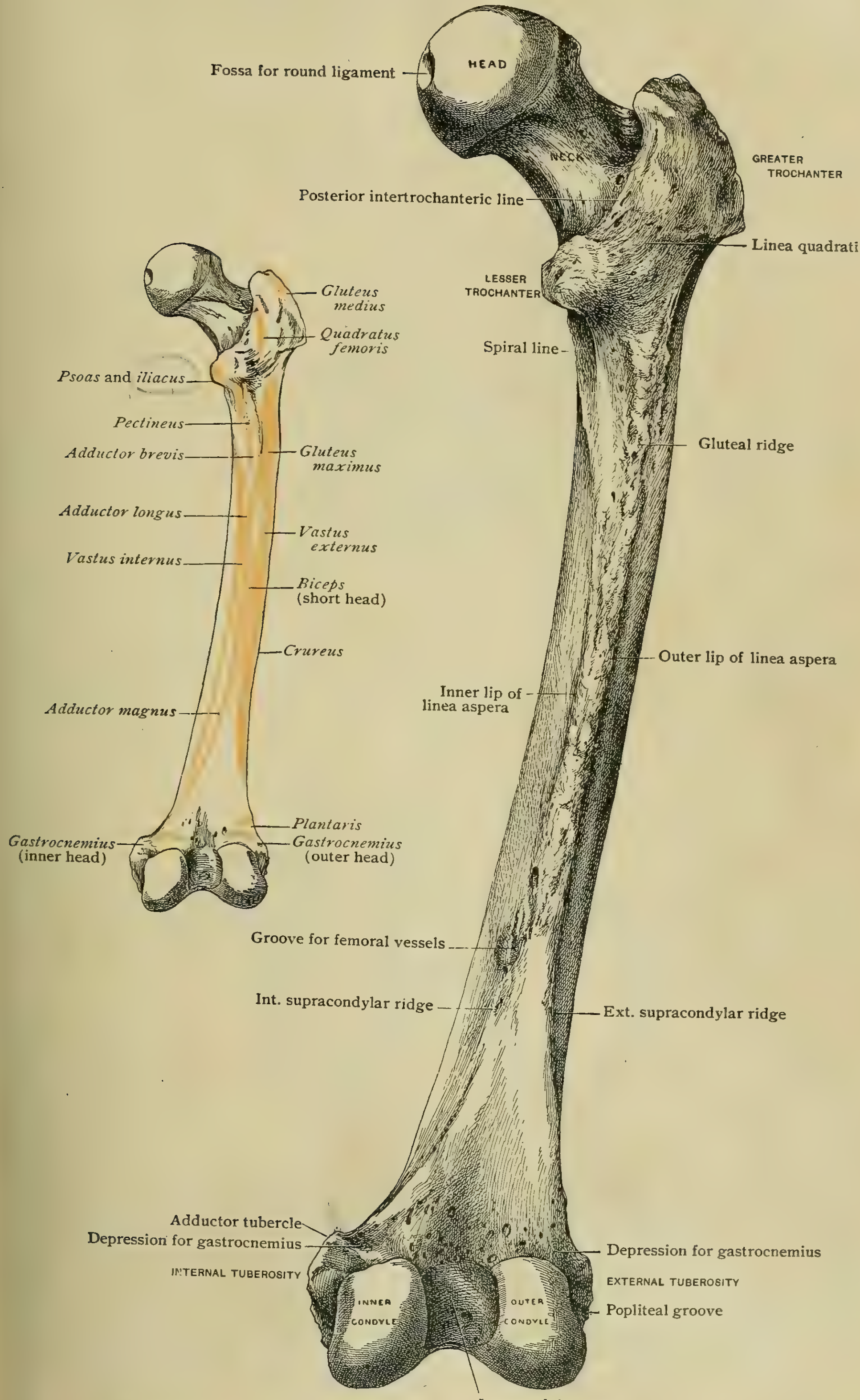
[1] Fossa trochanterica. [2] Trochanter minor. [3] Corpus femoris.

FIG. 370.



Right femur from before. The outline figure shows the areas of muscular attachment.

FIG. 371.



Right femur from behind. The outline figure shows the areas of muscular attachment.

prominence of the linea aspera at the back. The surface on either side of this line may be plane, concave, or convex, perhaps more often concave. The shaft expands slightly above, where it is roughly four-sided with rounded borders. A ridge, which is very variously developed, often runs from the lower side of the neck, separating the anterior and internal surfaces. When strong, it emphasizes the concavity of the former. The lower third of the shaft broadens.

The **linea aspera**[1] is a prominent longitudinal ridge along the back of the middle third of the bone, strengthening the concavity and giving attachment to many muscles. It has two more or less well-defined borders or *lips*. It is formed from above by the union of three lines : the spiral, a faint intermediate line coming down from the lesser trochanter, and a third external one coming from the back of the greater trochanter. The upper part of the last is called the *gluteal ridge*, as it receives fibres of the gluteus maximus. This part may be considerably elevated, especially in muscular subjects, into a rough knob, the *spurious third trochanter*. The *true third trochanter*, which is sometimes seen at this point, is a smooth rounded eminence, the analogue of the third trochanter extensively found among mammals and particularly developed in the odd-toed ungulata. This is sometimes best developed on delicate female femurs with no rough muscular ridges. Of course the two forms may coexist. A rough elongated depression, the *fossa hypotrochanterica*, also receiving fibres of the gluteus, is sometimes found outside the gluteal ridge. The linea aspera divides somewhat below the middle of the bone into two **supracondylar ridges,** which bound a triangular space[2] as they pass down to the tops of the condyles. The *outer ridge* is at first much the sharper, but it becomes indistinct an inch or more above the condyle. The *inner* is but slightly raised ; it is interrupted above its middle for the passage of the femoral vessels into the popliteal space. It ends in the sharp *adductor tubercle* above the inner border of the condyle. At its termination the shaft has four *surfaces* : a posterior one nearly plane, a front one slightly convex, a distinct outer one, and an oblique inner one, passing insensibly backward and inward from the anterior surface. There are usually two *nutrient foramina*, both directed upward, the larger between the lines converging to the linea aspera, the other near the middle of the bone, a little to the inside of that line.

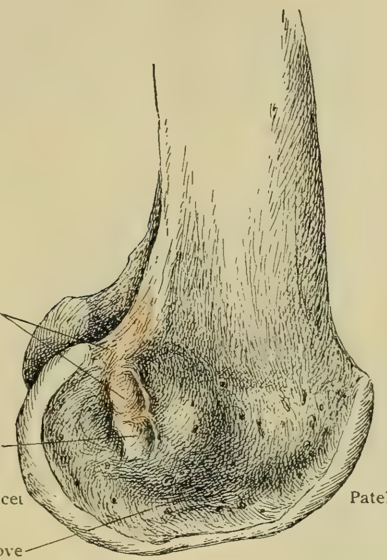
The **lower extremity,** articulating with the tibia below and the patella in front, presents two backward prolongations, the *condyles*, along which the tibia travels in flexion. These are compressed from side to side, and separated by the *intercondylar fossa*,[3] which is beneath the back part of the shaft. The *inner condyle*[4] is the lower when the shaft is vertical, but in life both are in the same plane. The *outer*[5] is longer from before backward ; it lies in an antero-posterior plane, while the inner extends backward and inward. The lateral outline of each has been well compared to a watch-spring partly uncoiled. Each bears a *tuberosity* near the posterior end of the lateral side, very nearly in continuation with the supracondylar ridges for the so-called lateral ligaments of the knee. A *depression* on each side for the head of the gastrocnemius is found above and behind the tuberosities. The external condyle bears a deep oblique *groove* for the tendon of the popliteus at the back of the outer surface.

The *articular surface* for the knee not only covers the lower and posterior aspects of the condyles, but is prolonged upward on the front for the support of the patella, as a groove which is shown by horizontal sections to be concave in the middle and convex at either side. The upper boundary slants upward and outward, the shaft just above it presenting a slight depression. Its outer border is a prominent ridge resisting outward dislocation of the knee-pan. The *patellar surface* is continuous with the articular facets of the condyles, being marked off only by certain lines, which, though distinct on the fresh cartilage, are often obscure on the dried bone, representing the separation of these joints. In some animals the separation is complete. The *outer line*, usually concave posteriorly, runs obliquely inward to just in front of the intercondylar notch. The *inner*, less clear and generally straight, begins much farther forward and runs obliquely backward to the inner side of the front of the notch. The outer in particular marks a distinct change of level. Behind these lines the articular surfaces extend along the lower and posterior sides of the condyles even onto the upper aspect, so as to allow extreme flexion of the knee.

[1] Linea aspera. [2] Planum popliteum. [3] Fossa intercondyloidea. [4] Condylus medialis. [5] Condylus lateralis.

Frontal sections through the back part of the condyles show that the inner is nearly symmetrical in its convexity from side to side, while the inferior surface of the outer

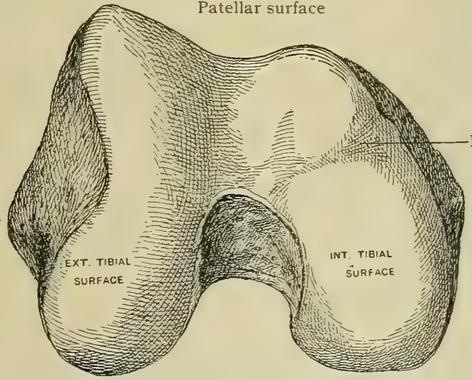
FIG. 372.



Lower end of right femur, outer aspect.

slants upward and inward. The length of the articular surface of the inner condyle from the back to the line marking off the patellar facet is considerably greater (perhaps two centimetres) than that of the outer.

FIG. 373.

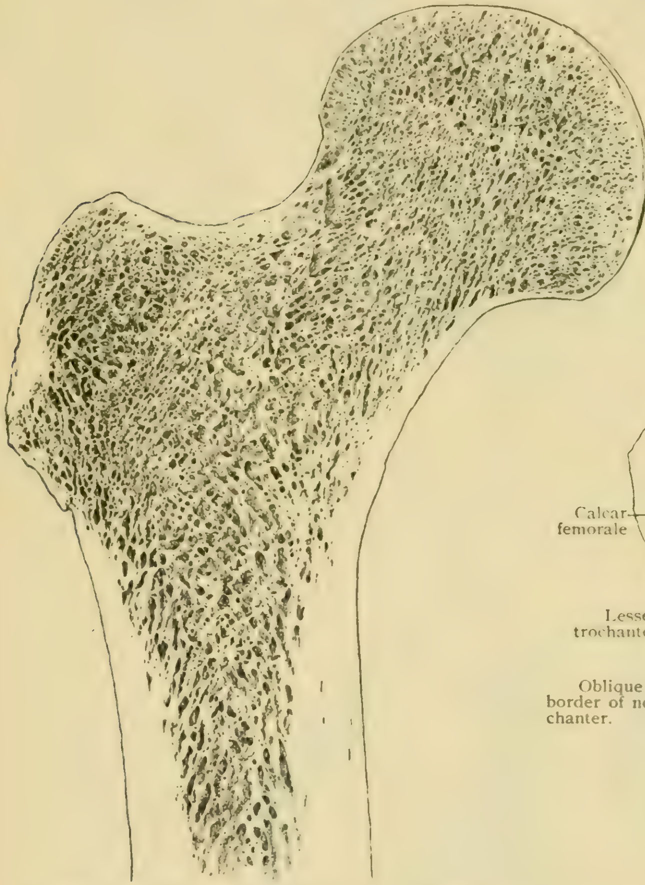


Lower end of right femur from below.

Structure.—Transverse sections in series through the whole length of the femur are very instructive. They show the great strength of the shaft, the thickness of its walls, the smallness of the central canal, and the addition made by the linea aspera ; likewise that the shaft becomes four-sided both above and below, and that in the latter region the greater diameter is transverse. Coincident with these changes are a great diminution of the thickness of the walls and a great increase of the spongy tissue. The weakness of the walls just above the knee is very striking. The architecture of the condyles is well exhibited, consisting of vertical plates run-

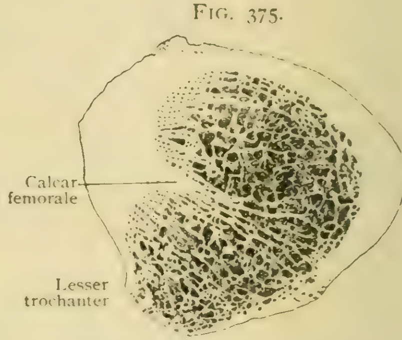
ning in the main forward and backward, crossed by transverse ones, in part diverging from the solid bone at the bottom of the intercondylar notch. Such sections show also the prominence of the outer border of the patellar surface and the curve of that articulation. At the upper end they display the prominence of the lesser trochanter, the series of strong plates crossing it, which at a higher level are seen diverging from a single plate, Bigelow's *true neck*[1] (Merkel's *calcar femorale*[2]), to which we shall return. The greater trochanter, quite free from all pressure, is very light and the head very dense. Frontal sections of the head and neck (Fig. 374) show the series of plates given off successively from both the inner and outer walls forming Gothic

FIG. 374.



Frontal section through upper end of femur, showing arrangement of pressure and tension lamellæ.

FIG. 375.



Oblique section of right femur parallel to lower border of neck, through upper end of lesser trochanter.

arches at the top of the bone. The under side of the neck is thick and gives off a series of plates, near together, running obliquely up into the head in the line of the greatest pressure, especially when the shaft is oblique, as in life. A less distinct series of long arches springs from the outer side, curving across, and acting as "ties." The head is of the round-meshed pattern, fitted to resist pressure in any direction, often presenting an almost solid core at the middle, and generally showing the curved line of union of the epiphysis of the head. The *true neck* of the femur is a plate, or a series of plates, springing from a thick spur of bone, which leaves the hind wall of the neck to run outward towards the greater trochanter. This is best

[1] The Hip, Philadelphia, 1869; also Boston Medical and Surgical Journal, 1875.
[2] Virchow's Archiv, Bd. I., 1870.

seen in sections parallel with the lower wall of the neck (Fig. 375) ; it appears also in transverse ones. When strongly developed it can be shown as a real septum by gouging away the spongy tissue of the posterior intertrochanteric ridge beneath which it passes.

Sexual and Individual Variations.—Apart from general lightness of structure, the female femur presents distinctly smaller articulations than the male. The average diameter of the head of thirty-eight male bones is 4.8 centimetres, and of twenty-six female ones 4.15 centimetres. In only two of the male bones is the diameter less than 4.5 centimetres, and in only two of the female is it greater. Both of the latter are long ones. In women the size of the head increases with the length, but in men a short femur is about as likely to have a large head as a long one. The breadth of the articular surface of the knee is less conclusive ; the averages are 8.3 centimetres and 7.4 centimetres, but there is much overlapping. The peculiarity of outline in the typical female femur is very characteristic when well marked : the shaft narrows gradually from the condyles till at or above the middle the narrowest part is reached, above which there is a much less evident expansion. The typical male bone narrows much more suddenly above the condyles, so that the stouter shaft soon reaches a tolerably uniform thickness. The *inclination of the shaft* is somewhat greater in woman. The angle with a vertical line in the above series is 9.3° in man and 10.6° in woman. (According to Bertaux, it is 8.75° and 11°.) It is naturally greater in shorter femurs, and consequently is of very doubtful value as a sexual characteristic, especially in view of the great individual variation. The *angle of the neck with the shaft* is of minor significance. In the writer's series it ranges from 110° to 144°, the average for men being 125.1° and that for women 125.6°. In the male bones there is little connection between the length of the femur and the size of the angle ; in women long bones have a large angle and short bones a small one. The average angle of the longer half of the male bones is 126.5° and that of the shorter 123.6°, while the longer and shorter halves of the female series give 129.2° and 121.9° respectively. A long neck generally has a high angle and a short neck a low one.[1] Thus it appears that there are great variations in the angle of the shaft and that of the neck. The same is true of almost every detail. The *forward inclination of the neck* is in two-thirds of the cases from 5° to 20°, and usually from 12° to 14°. Its extreme is 37°. Very rarely this angle is negative,—that is, the neck slants backward. An extreme negative angle of 25° has been observed, but this is extraordinary.[2] The curve and outline of the shaft vary much. An extreme form is the pilastered femur, very convex, with a prominent linea aspera, generally stout, implying strength. An opposite form is nearly straight, has a low linea aspera, and is flattened before and behind in the upper part of the shaft. In extreme forms the depression in the front of the top of the shaft is increased and bounded internally by a sharp ridge running up to the under side of the neck, which usually has a low angle. Though apparently weaker, this form is sometimes found in very powerful men.

The **index of the shaft** is the proportion of the thickness to the breadth, the latter being 100. Thus $\left(\frac{\text{thickness} \times 100}{\text{breadth}}\right)$. This is taken at about the middle of the shaft where the linea aspera is most prominent. It is said to be greater on the right than on the left and in men than in women. Bertaux found the average in adults 104.4, and in a series of young femurs 112.1.

The **index of the neck** is the proportion of the thickness to the height. Thus $\left(\frac{\text{thickness} \times 100}{\text{height}}\right)$. The average is 133.05. It is a trifle higher in women, but the difference in unimportant.

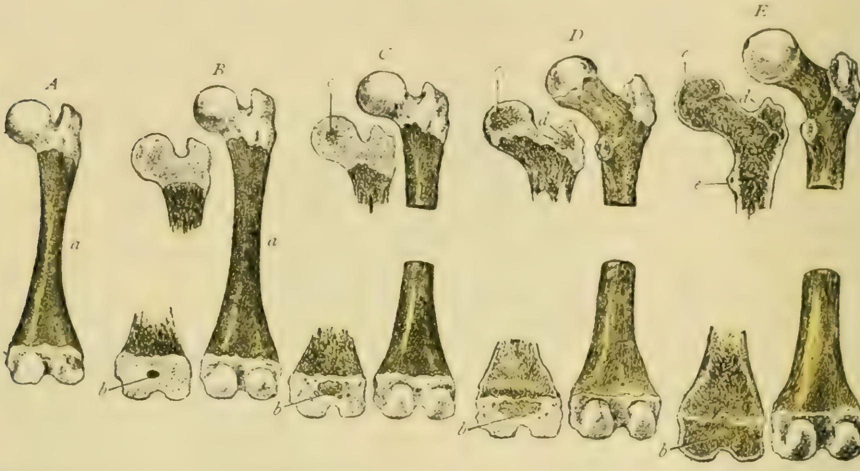
A strong convexity of the shaft outward as well as forward suggests a pathological condition.

Development and Changes.—The shaft begins to ossify not later than the seventh week of fœtal life. A centre appears in the lower end during the last month of pregnancy. It is rarely wanting at birth, but the precise time of its appearance as well as its size are too variable to make it a very valuable guide to the age of the

[1] H. H. Hirsch : Anatomische Hefte, Bd. xxxvii., 1899.
[2] Mikulicz : Arch. für Anat. und Phys., 1878.

fœtus or infant. Its growth seems to be slight during the first three weeks after birth. The neck grows as a part of the shaft and receives three epiphyses,—one for each trochanter and one for the head, which fits over it like a cap. The latter appears in the second half of the first year,[1] and is pretty conclusive evidence that the age of six months at least has been reached. The epiphysis for the greater trochanter comes in the third year (sometimes some years later), and that for the lesser at a time variously stated as from eight to fourteen years. It is probable that

FIG. 376.



Ossification of femur. *A*, at eighth fœtal month; *B*, at birth; *C*, during first year; *D*, at eight years; *E*, at about fifteen years. *a*, centre for shaft; *b*, lower epiphysis; *c*, for head; *d*, for greater trochanter; *e*, for lesser trochanter.

the former is much nearer the mark. The head unites with the shaft at about eighteen, the trochanters somewhat later; probably there are great variations; but all these superior epiphyses should be joined by nineteen, and at twenty the line of union is indistinct or lost. An epiphysis for the third trochanter has been seen. The lower epiphysis is joined by twenty, and often sooner. At birth the angle of the neck may be 160°, but is often less; it diminishes under the pressure of the weight as the child walks, and by the time of puberty has probably assumed about its permanent angle. There is no reason to believe that the angle diminishes in old age.

Surface Anatomy.—The greater trochanter can be explored when the muscles about it are relaxed. The lesser trochanter, though deep, can be felt from behind. A large third trochanter can be recognized, and must not be mistaken for a tumor. Owing to the individual variations of the neck and the pelvis, the relations of the trochanter must vary. According to Langer, a horizontal line at the top of the greater trochanter divides the head, touches the top of the symphysis, and about divides the nates. This is particularly true of broad pelves, and therefore of women. We have found from measurements of 118 males and 37 females that the trochanter is 1.1 centimetres, on the average, higher than the symphysis in the male and three millimetres in the female. Topinard gives as provisional distances in the male the following: the anterior superior spine of the ilium is six centimetres above the head of the femur, the latter two centimetres above the greater trochanter (practically agreeing with Langer), and the greater trochanter two centimetres above the pubes. The head of the femur lies under a crease beneath the proper fold of the groin, and can sometimes be distinguished at the inner side of the sartorius. Nélaton's line is drawn from the anterior superior spine of the ilium to the most prominent point of the tuberosity of the ischium. It should just touch the top of the greater trochanter. The shaft is too thickly covered to be examined in detail, except near the knee. The sides of both condyles are easily examined; the lateral tubercles and the adductor

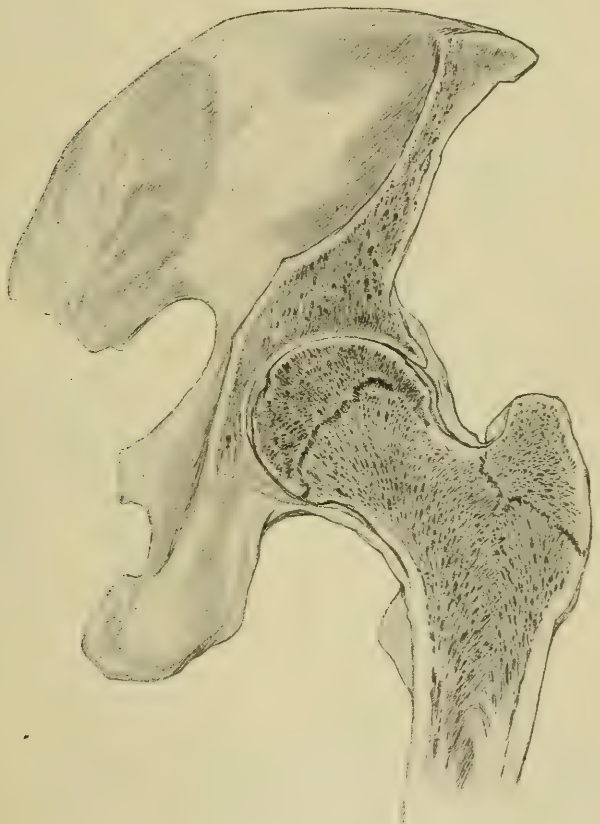
[1] Fagerlund: Wiener Med. Presse, 1890.

tubercle can be felt. The latter marks the line of union of the lower epiphysis with the shaft. When the knee is flexed, the patellar surface, its borders, and part of the articular surface of the condyles can be felt.

PRACTICAL CONSIDERATIONS.

Before the age of four the upper epiphysis is not distinct, and traumatism is apt to result in separation of the upper cartilaginous end of the bone,—*i.e.*, a fracture through some part of the cartilaginous neck. Later three epiphyses may be affected by injury,—viz., those for the head and the two trochanters.

FIG. 377.



Section through hip-joint, showing epiphyses of head and greater trochanter of femur.

The *epiphysis for the head* is shaped like a hollow hemisphere set upon the convex upper end of the neck. The epiphyseal line slopes downward and inward, and is entirely within the synovial membrane.

Separation by indirect violence occurs as a result of extreme extension of the thigh, as in falls backward with the limb fixed, or as when a child carried in the arms of a nurse throws itself violently backward. The force is thus in effect applied at the lower end of the femur, which acts as the long arm of a lever. When it is carried far backward the ilio-femoral ligament is put upon the stretch, and its point of insertion becomes the fulcrum. The resistance (or weight) is at the point where the forward movement of the short arm of the lever—the neck and head—

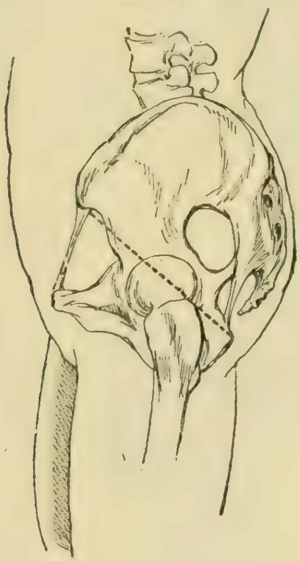
is resisted, perhaps slightly, by the ligamentum teres, but chiefly by the anterior margin of the acetabulum.

Separation is followed by shortening. This may be recognized by Nelaton's line (Fig. 378), by the base line of the "ilio-femoral triangle" (Bryant's) (Fig. 379), or by Robson's line, which is a line dropped vertically from the anterior spine to meet a transverse line drawn forward and inward from the tip of the greater trochanter across the front of the thigh, the patient being in dorsal decubitus.

Eversion, from the weight of the limb, is usually present.

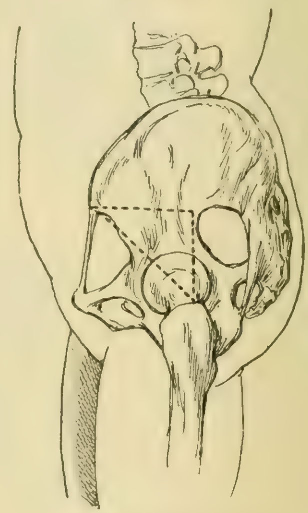
The toughness of the periosteum and the strength of the cartilaginous bond between the neck and head in childhood may make the epiphyseal line stronger than the thin neck beneath it, and fracture of the neck may therefore occur even in young children or adolescents. The symptoms are very similar to those of epiphyseal separation. The crepitus may be rough instead of "muffled." The X-rays will sometimes differentiate the two conditions. In a case of injury to the hip in a young person, it is, however, probable that epiphyseal disjunction will result rather than fracture of the neck; but in youth, on account of the presence of the epiphyseal

Fig. 378.



Showing Nélaton's line.

Fig. 379.



Showing Bryant's triangle.

joint and the weakness of the neck, both of these lesions are more frequent than dislocation. Either of them will convert the normal obliquity of the neck to a position more nearly horizontal, causing prominence and ascent of the trochanter, and bringing about at once the condition known as coxa vara, which will probably increase later, as whenever the angle of the neck with the shaft is diminished the strain upon the former is increased. Thus, either epiphyseal separation, fracture of the neck, or slight rhachitis in early childhood may result in coxa vara at the period of adolescence, when the softening incident to rapid growth is taking place, the body weight is increasing,—often disproportionately,—and laborious occupations are frequently begun.

The *epiphysis for the greater trochanter* unites at about the nineteenth year. It is easily dislocated, almost always from direct violence, and usually between the thirteenth and eighteenth years, because that is the period of greatest exposure to traumatism, and because at the latter date the epiphysis is joined to the shaft. The line of junction with the shaft is on the level of the tubercle for the quadratus on the posterior edge of the greater trochanter (Fig. 383). It is therefore below the level of the capsule of the hip-joint and of the insertions of the glutei, obturators, pyriformis,

and gemelli. Disjunction from indirect violence—through the action of these muscles—is rare, on account of: (1) The prolongation downward and outward of the fibres of the capsular ligament which extend below the epiphyseal line. (2) The attachment above that line of some of the aponeurotic fibres of origin of the vastus externus. (3) The toughness of the periosteum.

For these same reasons, when disjunction does occur, there is usually but little displacement. If it exists, and is marked, the epiphysis is drawn into approximately the same position as that occupied by the head of the bone in a dislocation onto the dorsum of the ilium. The age of the patient (epiphyseal separation being impossible after nineteen and dislocation rare before that age) and the failure of the displaced epiphysis to move with rotation of the femur are aids to diagnosis. The absence of rotation and of shortening of the limb distinguishes this lesion from "extracapsular" fracture of the neck.

FIG. 380.

Lines of fracture of femur.

About fifty per cent. of the recorded cases have died of pyæmia. This is probably because: (1) The greater trochanter is an apophysis rather than an epiphysis, and is in contact at its base with cancellous tissue of a lighter and more spongy character than that adjoining the true terminal epiphyses of the long bones. (2) The violence causing the injury is direct and thus associated with much bruising and crushing of that tissue. (3) The disjunction is attended by extensive detachment of the periosteum from the vascular upper end of the bone, as the periosteum over the trochanter is very thin and the dense tendinous fibres are almost directly attached to the osseous tissue itself (Poland).

The *epiphysis for the lesser trochanter* can be separated usually only between the thirteenth year and the nineteenth, when it joins the shaft. But one case has been recorded. It was then torn off in a boy of fourteen, as the result of the strain on the iliopsoas in a fall backward on the feet. Death from pyæmia followed.

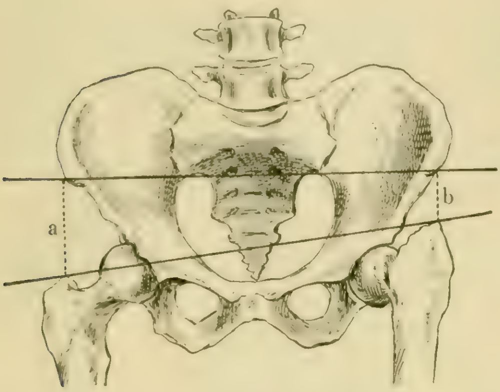
Fracture of the neck of the femur is common (especially in old age), in spite of its depth and its thick covering of soft parts, because: (1) In falls upon the feet or hip it receives and transmits much of the weight of the body, which, in the former case at least, reaches it in a direction which causes a cross-strain favorable to fracture. (2) It is a comparatively fixed portion of a very long lever into the upper end of which many powerful muscles are inserted. (3) It is of itself lengthened and thus made more vulnerable,—as compared, for example, with the neck of the humerus,—so as to increase the leverage of these muscles, the degree of mobility of the hip-joint, and the basis of support for the trunk. (4) Its mechanical weakness increases in old age (*a*) from the absorption of cancellous tissue which occurs everywhere in the skeleton, but begins and proceeds most quickly (according to Humphry) in the femoral neck; (*b*) from a corresponding thinning of the compact tissue, including that part of the cortex which unites the lesser trochanter and the under and anterior part of the head, the line of greatest pressure in the erect position. (5) The angle between the neck and the shaft is believed by many surgeons gradually to decrease, though this change is not invariable and is denied by some excellent authorities. It is true, however, that the angle is smaller the less the stature; that it is thus smaller in women, and that in them, after the age of fifty, these fractures are two and a half times more common than in men.

When the age of the patient is advanced, and the violence is slight and indirect, the femoral neck breaks more frequently near its junction with the head, because there it is thinnest and weakest. Such fractures are entirely intracapsular.

In younger persons, and especially if the violence is severe and is received directly upon the hip, the fracture is more apt to involve the base or wider portion of the neck, and is likely to be partly intra- and partly extracapsular. If it is

entirely below the line of capsular attachment both in front and behind, it cannot be a fracture of the neck, as it would then be below the anterior intertrochanteric line, and would involve the extreme upper end of the shaft. Posteriorly, it is possible for a partial fracture of the neck to be extracapsular, as the insertion of the capsule is from twelve to seventeen millimetres (one-half to two-thirds of an inch) above the base of the neck. Impaction of fracture at the narrow part of the neck is not very common. When it occurs, some spicula of the compact cortex of the neck are driven into the expanded cancellated structure of the head.

Fig. 381.



Showing elevation of tip of trochanter and shortening of base of Bryant's triangle in fracture of neck of femur; *a*, base on sound side; *b*, on fractured side.

Impaction of fracture at the base is common, because the spongy trochanter is easily thrust upon and sometimes split by the small and relatively compact cervix.

In most fractures of the neck there will be found :

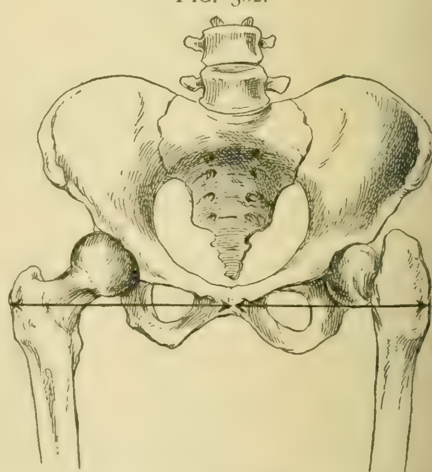
(1) Eversion, due chiefly to (*a*) the weight of the limb, which tends normally to roll outward ; but also to a certain extent to (*b*) the action of the ilio-psoas and other external rotators ; (*c*) the greater comminution or crushing of the posterior wall of the neck, which is weaker than the anterior wall.

(2) A fulness over the upper portion of Scarpa's triangle, due to effusion into the hip-joint or to forward projection of the fragments against the front of the capsule. This is likely to occur because the neck is normally convex forward, the lesser trochanter, marking the inner and lower boundary of the neck, being on a plane posterior to the head ; and because of the greater destruction of the posterior portion of the neck.

(3) Relaxation of the ilio-tibial band of the fascia lata (page 367).

(4) Approximation of the trochanter to (*a*) the anterior superior spine, as shown by shortening, best determined by the length of the horizontal side or base of the ilio-femoral triangle ; and to (*b*) the mid-line of the body, as shown by Morris's line. Nélaton's line shows the former, but involves more disturbance of the patient. Chiene demonstrates shortening by placing the edge of a straight flexible piece of metal on the two anterior spines and that of another on the tips of the two trochanters. Parallelism negatives the idea of fracture. Morris measures from the symphysis pubis to the external trochanteric surfaces. The distance is lessened on the side of fracture.

Fig. 382.



Morris's measurements to show the trochanter of the injured side nearer the median line in fracture of neck of femur.

These points can easily be understood by reference to Figs. 381 and 382.

Emphasis is placed on these measurements because it is perhaps more important in this than in any other fracture to avoid vigorous efforts to elicit crepitus.

The blood-supply of the proximal fragment—the head—will reach it only through the reflected portions of the capsule, untorn strips of periosteum, and the ligamentum teres, that through the cervix being cut off. It is, therefore, scanty and

may be insufficient to furnish reparative material. Any movement that might tear the remaining connections between the fragments is, therefore, most undesirable. The great length of the lower fragment, and the leverage thus exerted as a result of any motion of the inferior extremity, together with the action of the powerful muscles running from the pelvis to the thigh, make it especially difficult to keep the fractured surfaces in close apposition, particularly if the small part of the neck is involved. Impaction, even if very slight, may thus be a favorable circumstance, and should not be broken up by rough handling.

Intracapsular fractures, in spite of the scanty blood-supply, the presence of synovial fluid, which is perhaps the most important unfavorable factor, and the mobility of the lower fragment, do unite, but rather as an exception. As a rule, fractures at the base of the neck unite.

FIG. 383.

Showing epiphyses of femur.

Fracture of the shaft is most common at the middle, at the point of greatest convexity of the forward curve, in spite of the fact that here the bone is denser and its compact outer wall thicker. At the upper third fracture is usually due to indirect violence, at the lower third to direct violence. In the former case it is apt to be oblique, in the latter transverse. These lesions, as well as those of the lower end, just above the condyles, will be considered in their relation to the muscles that influence them (page 644).

The *lower epiphysis* of the femur, the only one whose ossification begins before birth,—"with the exception of the occasional early appearance of the osseous nucleus in the upper epiphysis of the tibia" (Poland),—is the last to join its diaphysis, union occurring about the twentieth year. It has a cup-shaped upper surface, which is higher externally. Its internal level is just beneath the adductor tubercle. The epiphysis includes all the articular surfaces of the lower end of the femur.

In the majority of the cases of disjunction of this epiphysis the cause has been hyperextension of the tibia on the femur, often combined with some twisting and traction upon the leg, as when a boy hanging behind a cab has his foot caught between the spokes of a wheel. In twenty-seven out of sixty-eight cases the lesion was caused in this way.

The ligaments of the knee-joint are so powerful (as they must be for security, on account of the shape of the bones that enter into it) that when the leg is brought into overextension tremendous leverage is exerted on this epiphysis through the crucial ligaments, the external and internal lateral ligaments, and the popliteus muscle, aided by the gastrocnemius. Although the latter is attached partly above the epiphyseal line, the periosteum is torn off the lower end of the diaphysis down to the extremely dense layer at the cartilaginous junction. The muscle then becomes an important factor in carrying the epiphysis forward—the usual displacement—and, aided by the popliteus, in rotating its posterior upper edge downward. The mechanism has been compared to that of fractures of the radius in falls upon the hand, the posterior ligament of the knee-joint bringing a cross-strain upon the epiphysis similar to that conveyed to the radius by the anterior ligament of the wrist.

The diaphysis projects into the popliteal space or through the skin, and has caused grave injuries to vessels and nerves. Amputation has been required in a large proportion of these cases, on account of these injuries or because of the detachment of the periosteum and the suppuration that often follows it. The joint is rarely involved, because the ligaments uniting the bones of the leg to the epiphysis are more powerful than the cartilaginous connections of the latter with the diaphysis.

As might be expected, the chief growth of the femur taking place from this

epiphysis, a number of cases of arrest of growth have been reported. The disjunction has been mistaken for a dislocation of the knee or a supracondylar fracture of the femur, but the undisturbed relations of the condyles and the head of the tibia and the freedom of motion in the knee-joint serve to distinguish it from the luxation, while the fracture is rare in children, and presents differential signs that will be mentioned later (page 644).

Fractures between the condyles (intercondylar), when T-shaped, as they often are, are thought to be secondary to the main or supracondylar fracture,—*i.e.*, the shaft breaks above the condyles and the force continuing splits them apart. The line of the latter fracture is nearly vertical and follows the intercondylar notch, already weakened by numerous foramina for vessels. The proximity of the popliteal vessels has resulted in grave complications from pressure or from rupture. Either condyle may be split off separately. The joint is necessarily involved in all these fractures, and rapid distention may make the diagnosis difficult. The X-rays should, of course, be employed in such cases, and indeed in all doubtful fractures of the femur.

Osteotomy for genu valgum may be done through an incision on the outer side of the thigh—the region of safety—about two inches above the external condyle. The ilio-tibial band of fascia is cut ; the incision passes in front of the biceps ; when about two-thirds of the shaft has been divided by the osteotome, the remainder will fracture easily, as the outer part of the bone is here thicker than the inner. The operation has the advantages of remoteness from the epiphyseal line, from important blood-vessels, and from the synovial membrane of the knee. The bone is divided at a narrow part.

Disease.—Infective disease of the upper end of the femur usually involves the hip-joint, even when it begins in the diaphysis, the epiphyseal line being intra-articular.

In spite of the protective covering of muscles surrounding the shaft, it is not infrequently the subject of inflammation, probably as a result of the great strains and numerous traumatisms to which it is subjected, and of the physiological activity necessitated by its rapid growth, which between birth and maturity is proportionately nearly twice as much as that of the leg and more than twice as much as that of the whole body. Thus, post-typhoidal osteitis attacks the femur in about twenty-five per cent. of the cases in which the lower extremity is involved, and more frequently than any other bone except the tibia and ribs, although the superficial bones of the skeleton are involved by this disease three and a half times more frequently than the deep bones.

At the lower end of the femur, disease resulting in necrosis, especially of the posterior aspect, often requires amputation, as, owing to the thinness of the periosteum in that region, there is scarcely any attempt at the formation of an involucrum (Rose).

Exostoses of the femur are not uncommon, especially in horsemen, in the neighborhood of the tendon of the adductor longus—*i.e.*, at the upper end of the femur—and occasionally in that of the adductor magnus at the lower end,—"rider's bones."

The great comparative frequency with which sarcomata attack the femur is in accord with the general rule that they are more frequently found on long bones than on short ones, on the lower limb than on the upper, and on bones near the trunk than on those remote from it. As they are also more malignant the nearer they approach the trunk, these tumors, like those of the humerus, are clinically more serious than those of the distal portions of the extremity. Both central and subperiosteal sarcomata, but especially the former, have a predilection for the ends of the bones ; but whereas they affect chiefly the upper end of the humerus and the lower ends of the radius and ulna, in the inferior extremity they are most often found at the lower end of the femur and the upper ends of the tibia and fibula,—that is, at the ends towards which the nutrient arteries are not directed, and at which epiphyso-diaphyseal union takes place latest (page 272).

Landmarks.—In very thin persons the head of the femur can sometimes be felt immediately below Poupart's ligament and just external to its middle.

The greater trochanter is almost subcutaneous, being covered by the aponeurotic insertion of the upper fibres of the gluteus maximus. It is from 7.5 to 10 centimetres (three to four inches) below the crest of the ilium. In the erect position it is slightly anterior to and farther from the mid-line than the mid-point of the crest. It is visible in thin persons, and assumes abnormal prominence when there has been wasting of the gluteal muscles, as the gluteus medius and minimus normally efface the hollows between it and the ilium. In fat or muscular persons the fascial attachments to the trochanter cause a visible depression. Its upper border is on a level with the centre of the acetabulum (so that Nélaton's line passes over those two points), is nineteen millimetres (three-quarters of an inch) lower than the top of the femoral head, and is almost on a level with the pubes. The depression immediately beneath it corresponds to the tendinous lower portion of the gluteus maximus close to its insertion. The gap between it and the iliac crest is bridged over by the upper portion of that part of the fascia lata known as the ilio-tibial band. Relaxation of this band in fracture of the femoral neck can be both felt and seen (Allis).

The three gluteal bursæ interposed between the trochanter and the gluteal muscles may become enlarged, especially that beneath the gluteus maximus, and obscure the outlines of the trochanter. This condition is sometimes mistaken for hip-joint disease, as the thigh is usually adducted and flexed on the pelvis, because abduction and extension bring into action the gluteal muscles, and thus cause painful pressure on the bursa. Inflammation of that bursa is almost always the result of a blow upon the trochanter ; the joint movements are free, there is no referred pain in the knee, and forcing the head of the femur against the acetabulum by pressure upon the knee is painless, as is pressure over the capsule of the joint below Poupart's ligament.

In subcutaneous osteotomy of the neck of the femur the incision for admission of the saw is made about one inch in front and one inch above the top of the trochanter. The saw cut runs parallel with Poupart's ligament and is about 2.5 centimetres (one inch) below it.

The lesser trochanter cannot be felt.

The shaft of the femur is deeply situated and cannot be closely approached for palpation, except at the outer side of the lower third in the space between the biceps and vastus externus.

The most prominent part of the inner rounded surface of the knee is the tuberosity on the inner condyle of the femur. Above it is the adductor tubercle marking the tendinous insertion of the great adductor and just above the inner end of the epiphyseal line.

The external condyle is subcutaneous.

The remaining landmarks in this region will be considered in relation to the knee-joint and the soft parts (page 671).

THE HIP-JOINT.

This is a ball-and-socket joint. The **socket** is formed by the acetabulum with the assistance of the *transverse* and *cotyloid ligaments*. The articular facet which bears the articular cartilage has been described. The notch at the lower part of the periphery of the acetabulum is bridged over by the **transverse ligament**[1] (Fig. 384), a collection of interlacing fibres, which thus completes the margin of the socket. An opening is left below it through which vessels and nerves pass ; from its sides the **round ligament**[2] arises. Some fibres of the transverse ligament mingle with those of the latter. The **cotyloid ligament**[3] (Fig. 384) is a fibro-cartilaginous rim, which deepens the socket overlapping the head of the femur until the cavity embraces more than half a sphere. It is attached to the edge of the acetabulum, and, where this is wanting, to the transverse ligament. The cotyloid ligament is about five millimetres broad at the attached base, and narrows to a sharp border, so as to be triangular on section. The distance from the base to the free edge is very nearly one centimetre at the top of the joint, where it is greatest. The non-articular space at the bottom of the joint is filled with fat and by the round ligament nearly up to

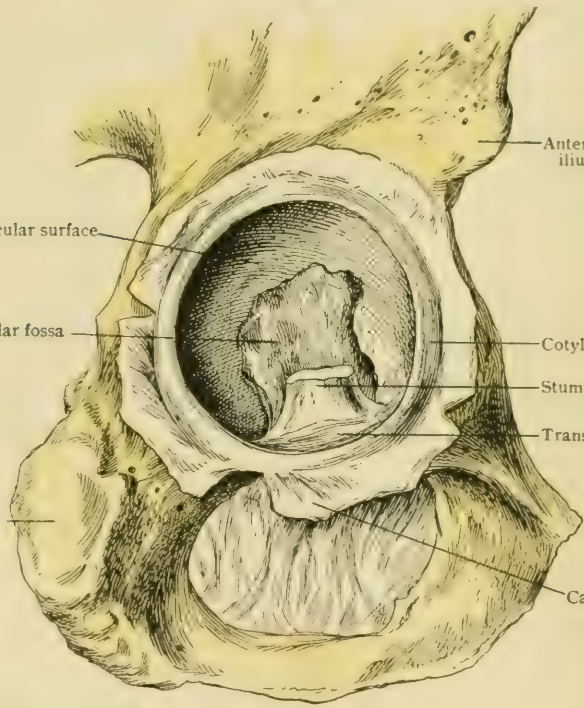
[1] **Lig. transversum acetabuli.** [2] **Lig. teres femoris.** [3] **Labrum glenoidale.**

the level of the articular surface. These structures are covered by synovial membrane. The head of the femur is covered by articular cartilage, except at the depression for the insertion of the round ligament.

The bones are connected by the *capsule* and the *round ligament.*

The **capsule**[1] (Figs. 385, 386) is a fibrous envelope enclosing the joint, strengthened by certain bands, which are inseparable parts of its substance, though they have names of their own. The capsule is attached to the cotyloid ligament and to the periphery of the acetabulum just outside of the origin of the latter. In this respect there is much uncertainty; the capsule always rises from the free edge of the transverse ligament, and, as a rule, elsewhere outside the base of the cotyloid; but it may in parts arise from its edge. This applies to the capsule examined from within; externally the fibres extend a considerable distance from the border of the joint. They almost conceal the opening at the notch below; above, they partly bridge over the reflected tendon of the rectus and partly join its deeper fibres. The capsule extends to the base of the anterior inferior spine of the ilium and some distance on the obturator crest. The attachment to the femur, seen from without, runs from the top of the greater trochanter, just above the superior cervical tubercle, down the spiral line to the level of the top of the lesser trochanter, where the line of insertion turns in for about two centimetres, when it passes upward along the back of the neck, less than half-way from the head to the posterior intertrochanteric line, till, reaching the top of the neck, it gradually passes outward to the starting-point. Thus the capsule stops about a finger's-breadth short of the lesser trochanter, includes less than half the hind side of the neck, and stops short of the digital fossa and of the inner side of the top of the greater trochanter. Posteriorly, it is not truly inserted into the neck, but simply crosses it, its position being determined by the line of reflection of the synovial membrane. The general direction of the fibres is longitudinal; but the posterior fibres, when the femur is strongly extended, assume the form of a twisted band running from the back of the socket outward

Fig. 384.



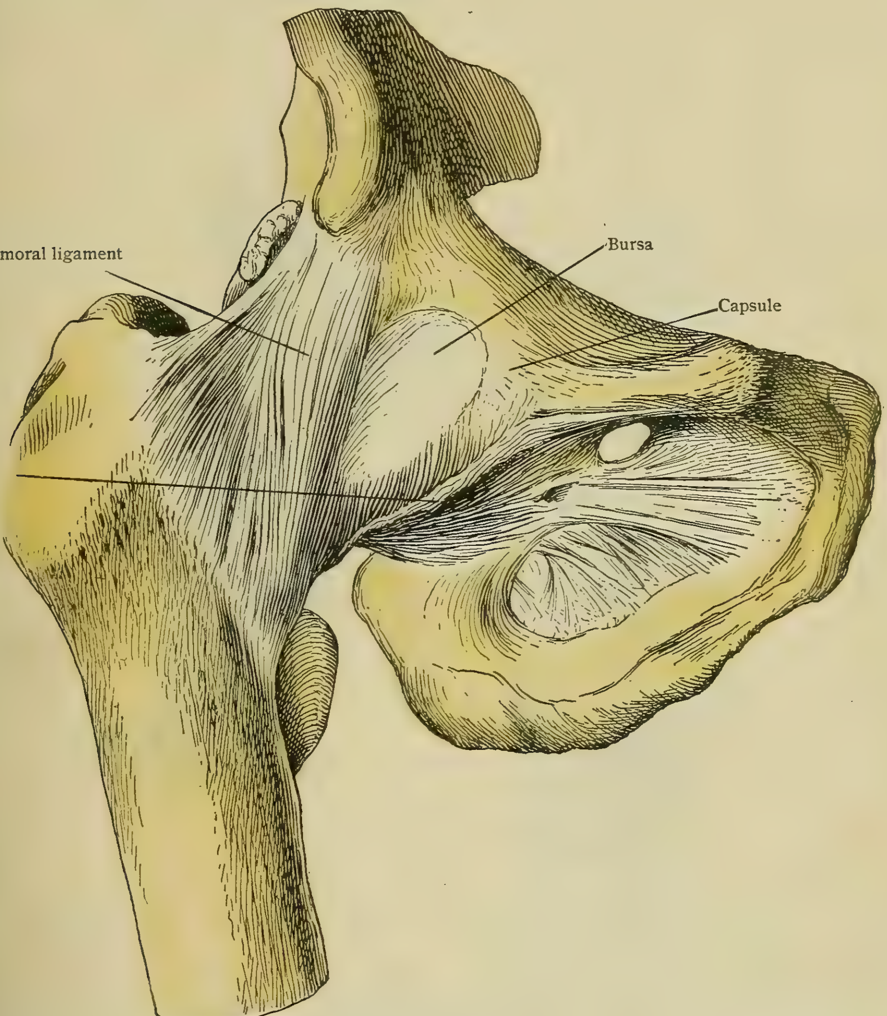
Socket of right hip-joint. The capsule has been divided near its origin and reflected.

[1] Capsula articularis.

and upward across the back of the neck to the top of the greater trochanter (Fig. 387). Moreover, beneath the longitudinal layer there is a sling of circular fibres, the *zona orbicularis*, starting from the anterior inferior spine of the ilium and passing behind the neck to return to the same point. It lies near the head of the femur, completely concealed by the longitudinal fibres. It is isolated only by a rather artificial dissection.

The capsule varies much in thickness in different places; thus, it is very weak behind and very strong in front. It is strengthened by three collections of accessory

FIG. 385.



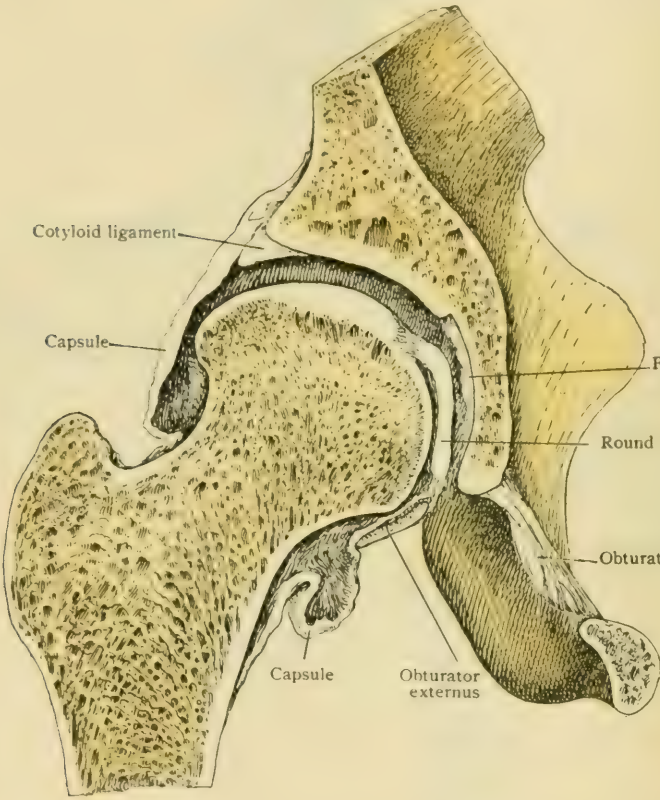
Right hip-joint, anterior aspect.

fibres. Much the most important is the **ilio-femoral ligament**[1] (Fig. 385), a thick triangular expansion, intimately fused with the capsule, arising by its apex from the lower part of the anterior inferior spine of the ilium and from the bone below and behind it above the lip of the acetabulum, and extending by its base from the superior cervical tubercle to the level of the lesser trochanter. The borders of this are often particularly strong, and are spoken of as the *outer* and *inner limbs* of the ligament. A weak space is sometimes seen between them near the insertion, whence it has been called by Bigelow the *Y-ligament* from a resemblance to an inverted Y.

[1] Lig. iliofemorale.

Striking examples of this are generally artificial productions. The beginning of the ilio-femoral ligament covers the outer part of the head. The capsule is much thinner over the inner part of the head, and is covered by the bursa under the ilio-psoas, which often communicates with the joint. The **pubo-femoral ligament**[1] (Fig. 385) is a slender band of fibres, thickening the under side of the capsule, extending from the lowest point of the capsular insertion on the spiral line to the outer end of the obturator crest. It is rarely very evident. The **ischio-femoral ligament**[2] (Fig. 387) is a strong but ill-defined bundle at the back of the joint, extending from the ischial origin of the capsule to the top of the digital fossa. The capsule is further supported by muscles and by bands of fibrous tissue, generally expansions from tendons or fasciæ. Morris describes a band on the upper

FIG. 386.



Frontal section through right hip-joint. The femur has been allowed to fall from the socket.

anterior aspect, passing between the reflected tendon of the rectus and the highest origin of the vastus externus, which is sometimes very strong, but, in our opinion, inconstant. The relation of the ilio-psoas has been mentioned. Fibres are received at the upper outer part from the gluteus minimus. The obturator internus and the gemelli are close against it behind, and the obturator externus behind and below. We have seen a tendinous band beneath the tendon of the obturator internus quite distinct from the capsule internally and fused with it externally. It may have been a reduplication of that muscle or an extra *ischio-femoral ligament.*[3]

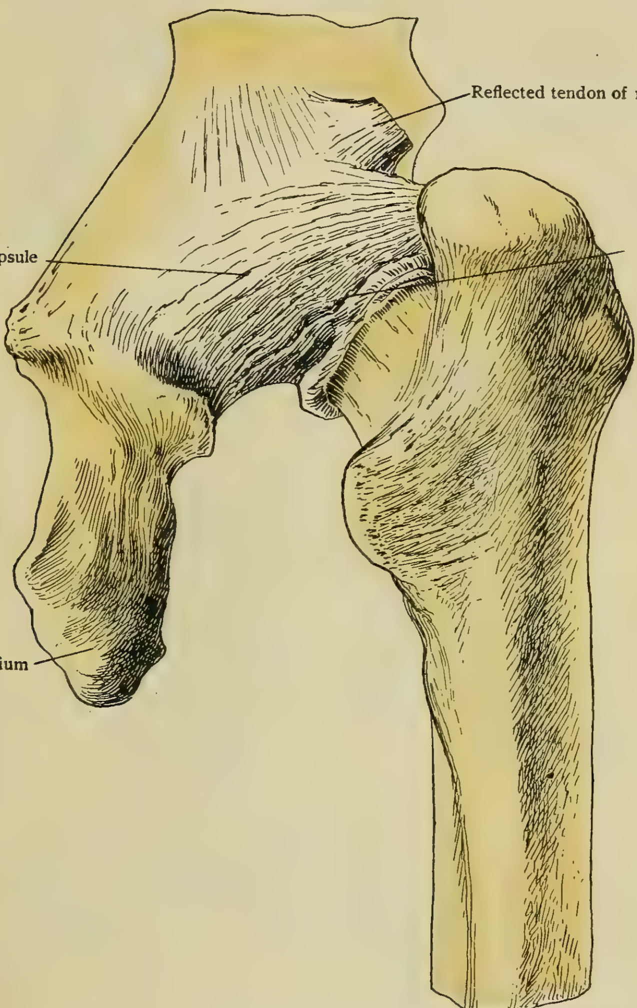
The **round ligament** (*ligamentum teres*) (Figs. 384, 389) is a weak band of fibrous tissue, containing vessels and nerves, surrounded by synovial membrane, lying under the fat in the deep non-articular hollow of the socket, connecting the

[3] Journal of Anatomy and Physiology, vol. viii., 1874.

[1] Lig. pubocapsulare [2] Lig. ischiocapsulare.

rim of the acetabulum with the head of the femur. The origin is from each edge of the notch and from the deeper fibres of the transverse ligament, the insertion into the deepest part and upper edge of the depression in the femoral head. A fresh specimen, especially from a child, shows the lower half of the depression becoming gradually shallower and forming a groove in which the upper part of the band rests, which, covered with the synovial membrane, completes the spherical shape of the head. Vessels run along the round ligament, which in infancy

FIG. 387.



Right hip-joint, posterior aspect.

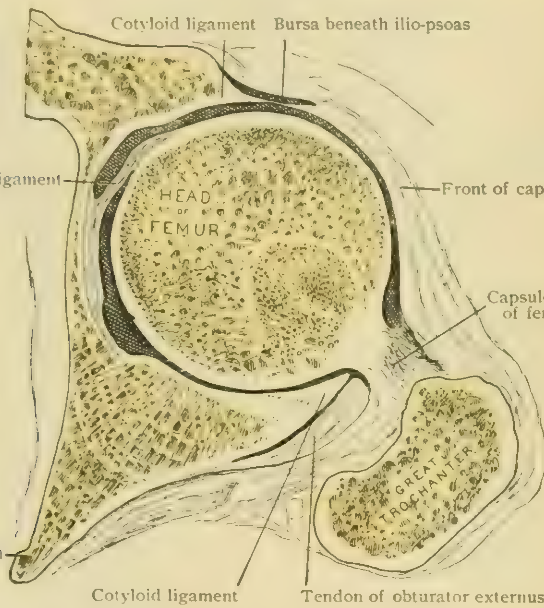
and early childhood nourish the head, but in the adult they often do not enter the bone.

This ligament is sometimes wanting. According to Moser,[1] this defect is only in the old, and is to be looked upon as a degenerative change. Comparative anatomy teaches that it is the analogue of a part of the capsule. It is remarkable that it is wanting in certain species closely allied to others possessing it. Besides the two extremes of complete freedom within the joint and of total absence, the ligamentum teres of animals is also found in an imperfectly developed condition as a fold along

[1] Schwalbe's Morpholog. Arbeiten, Bd. ii., 1893. This paper gives the literature.

the side of the cavity between the notch in the acetabulum and the head of the bone. Many of the statements of its absence require confirmation by more observations. Thus, among the anthropoid apes it seems to be generally present in all but the ourang. In this animal, though usually wanting, it has been found in a rudimentary condition. Meckel declared that it was absent in the gibbon, but we believe no other observer has had a similar experience. It is very strongly developed in the ostrich, but is wanting in the rhea (the American ostrich) and probably in the cassowary. Sutton[1] considers it as the tendon of the pectineus muscle which has become separated through skeletal modifications. Sutton relies a good deal on the condition in the horse for support in his argument. He found it consisting of two bands,—one within the joint, apparently the usual ligament, and another passing out of the cavity to the linea alba at its junction with the pubes, which he calls the pubo-femoral portion. The pectineus muscle arises in part from this latter portion. Sutton gives a table telling the story of the structure according to his theory. In sphenodon (a lizard) the tendon of the ambiens, representing the pectineus, passes

FIG. 388.



Horizontal section through right hip-joint.

into the joint to the head of the femur; in the ostrich the ligament is continuous with the tendon by means of connective tissue; in the horse the two parts are distinct; and in man the external part is wanting. The structure is evidently a very variable one.

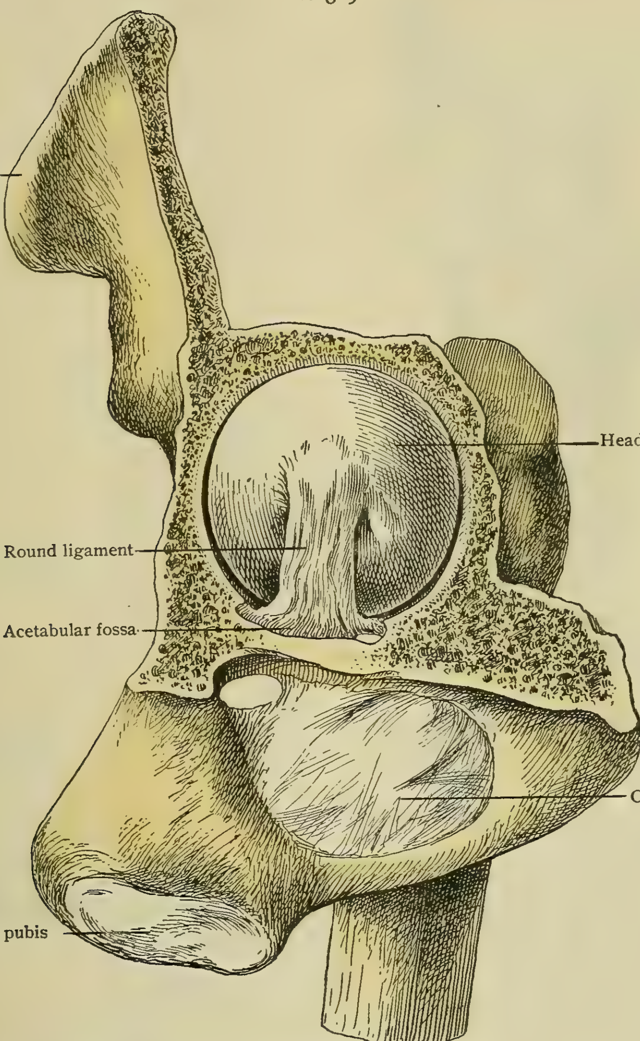
The **synovial membrane** (Figs. 386, 388) lines the capsule, covers the cotyloid and transverse ligaments, surrounds the ligamentum teres, and covers the fat in the fossa of the acetabulum. It is reflected from the femoral attachment of the capsule onto the neck, which it invests to the border of the articular cartilage. This reflected part presents certain folds caused by fibres from the capsule running up along the neck, called *retinacula* (Fig. 390). There are generally three chief ones: a *superior*, starting from the superior cervical tubercle and running along the upper border, or backward across the neck to the head of the femur; a *middle*, from near the inferior cervical tubercle along the front of the lower border of the neck; and an *inferior*, from near the lesser trochanter along the lower side. Any of these may be more or less free from the neck.

[1] Journal of Anatomy and Physiology, vol. xvii., 1883.

The retinacula[1] probably strengthen the union of the head and neck before the union of the epiphyses.

Movements.—As a ball-and-socket joint, the hip permits motion on an indefinite number of axes. If the ball were on the end of a straight rod, we could assume that flexion and extension occur on a transverse axis and adduction and abduction on an antero-posterior one, but the inclination of the shaft of the femur and that of the neck in two directions complicates the problem, so that accurate analysis of the

FIG. 389.



The inner wall of the hip-joint socket has been cut away, exposing the head and round ligament without disturbing the capsule.

movements is practically impossible. Rotation is motion on a vertical axis which is generally assumed to pass through the head and the intercondylar notch. This must, of course, vary with the shape of the bone. Although the angular motions in the four conventional planes are far from simple, they may be assumed to be so for practical purposes. *Flexion* is stopped in life by the contact of the thigh and the trunk before the limits of the motion are reached. *Extension* is limited by the

[1] Fawcett: Journal of Anatomy and Physiology, vol. xxx., 1896.

resistance of the strong ilio-femoral ligament, excepting the outer band. *Abduction* is limited, the thigh being extended, by the pubo-femoral ligament and perhaps by the inner limb of the ilio-femoral. When the thigh is flexed, the latter is certainly relaxed, and the strain comes on the pubo-femoral and a part of the capsule behind it,—a very weak region. *Adduction* with a straight thigh is limited by the outer limb of the ilio-femoral, the top of the capsule, and Morris's band from the rectus tendon to the vastus externus, if it be present. After moderate flexion is passed, the ilio-femoral is relaxed. *Outward rotation*, the thigh being straight, is checked by the ilio-femoral, especially by its inner band. As the thigh is flexed the inner band is relaxed and the outer is at first tense, but both are relaxed as flexion reaches about 45°. Morris's band now becomes tense, and as flexion becomes extreme the round ligament is tense also, unless the thigh be abducted, when it is completely relaxed. *Inward rotation* is checked by the ischio-femoral ligament in any position.

FIG. 390

Right femur seen from inner side, showing reflection of synovial membrane onto the neck.

The most important part of the capsule is the ilio-femoral band, which is extremely strong and prevents over-extension. It is an essential element in maintaining the upright position. The round ligament has probably no mechanical function, though it can be made tense by flexing, and at the same time either adducting the femur or rotating it outward. It is too weak to be of any real use as a restraint. Probably its chief usefulness is to carry vessels to the head of the femur in childhood.

PRACTICAL CONSIDERATIONS.

The greater security of the hip-joint, as compared with the shoulder-joint, is due to the depth of the acetabular cavity ; to its reinforcement by the cotyloid fibro-cartilage ; to the attachments of the ilio-psoas, gluteus minimus, and vastus externus to the capsule ; but chiefly to the thickenings of the capsule itself, which are described as the ilio-, ischio-, and pubo-femoral ligaments.

The greatest pressure upon the capsule in all ordinary positions is in an upward and outward direction, or upon the anterior surface of the capsule, as when, under the influence of the powerful extensors, the pelvis and trunk tend to roll backward upon the thighs in the erect posture. The tension and pressure are, of course, greatest near the pelvic attachment of the capsule where the head will impinge upon it with the most advantage as to leverage. The capsule is especially fitted to resist this pressure.

If two lines be drawn, one from the anterior inferior iliac spine to the inner border of the femur near the lesser trochanter, the other from the anterior part of the groove for the external obturator (*i.e.*, the upper part of the tuberosity of the ischium) to the digital fossa, all the ligament outside and above these lines is very thick and strong ; whereas, all to the inner side and below, except along the narrow pubo-femoral band, is very thin and weak, so that the head of the bone can be

seen through it (Morris). Fig. 391 represents this diagrammatically. In addition, the greater elevation and thickness of the upper and outer rim of the acetabulum, and the pressure against the trochanter exerted by the ilio-tibial band of the fascia lata (Allis) in adduction of the thigh (which means an outward movement of the upper extremity of the femur), should be mentioned among the factors that resist displacement. The ligamentum teres is of little value, as its bony attachment to the femoral head is easily separated by a force less than that required to rupture the ligament.

FIG. 391.

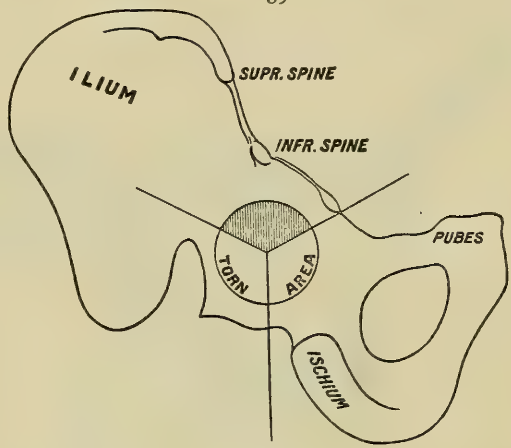


Diagram indicating strong and weak portions of capsule of hip-joint. (*Allis.*)

A line drawn from the anterior spine to the tuber ischii will approximately bisect the acetabulum and will divide each half of the pelvis into two planes, the pubo-ischiatic, inner or anterior, and the ilio-ischiatic, outer or posterior (Fig. 392). When the head of the femur escapes from the acetabulum it must lie on the surface of one or other of these planes. All dislocations are, therefore, either (1) outward—*i.e.*, posterior—or (2) inward—*i.e.*, anterior.

1. *Outward or Posterior Luxations.*—Traumatisms in which the force is expended upon the region of the hip result, as a rule, in children in epiphyseal separation (page 361), in old persons in fracture of the neck of the femur (page 363). In 173 cases of dislocation of the hip, 138 were between fifteen and forty-five years of age.

In practically all positions of the hip in which luxation is probable the force acts through some form of leverage which brings the short arm of the lever—always the head and neck of the femur—against a weak portion of the capsule. If it does this with the aid of a bony fulcrum, the power is exerted to the greatest possible advantage. Thus, in hyperextension of the thigh, the acetabular rim acts as a fulcrum, but the head of the bone is brought against the anterior part of the capsule,—the ilio-femoral ligament,—which is usually stronger than the bone itself. Hyperflexion is arrested by the contact of the soft parts of the front of the thigh with the abdomen; hyperadduction by the contact of the shaft with the pubes. Hyperabduction, however, brings the greater trochanter against the prominent outer lip of the acetabulum, while the head is carried downward against the thin inner and lower part of the capsule; the ilio-femoral and ischio-femoral ligaments are relaxed, and the weak pubo-femoral ligament offers but little resistance; the head, being opposite the shallowest part of the acetabulum, projects half its bulk out of that cavity; the weight—*i.e.*, the resistance of the capsule—is very close to the fulcrum, greatly increasing the power of the leverage.

FIG. 392.

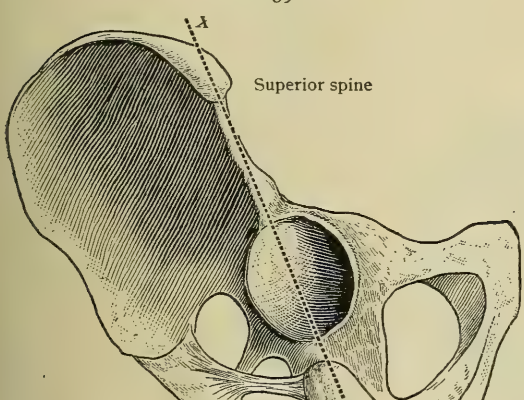
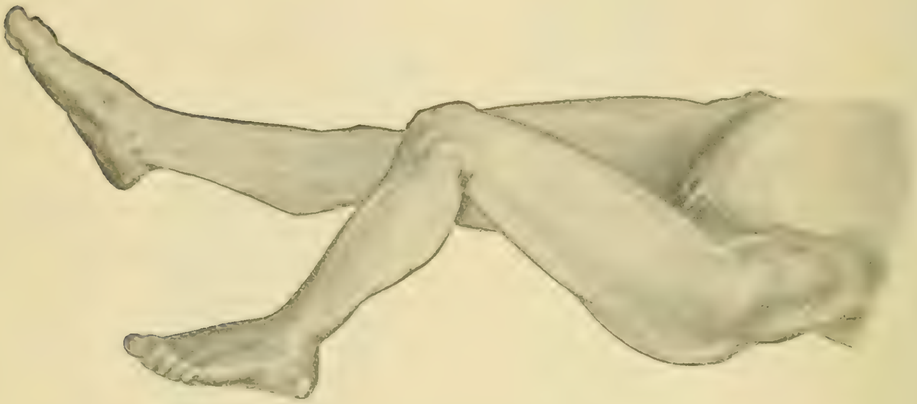


Diagram showing dividing line (X, Y) between outer and inner pelvic planes. (*Allis.*)

The ilio-femoral ligament may, in cases in which the thigh is adducted and rotated inward at the time of application of the force, take the place of the acetabular rim as a fulcrum. In that position it is wound round the neck of the femur, and

FIG. 393.

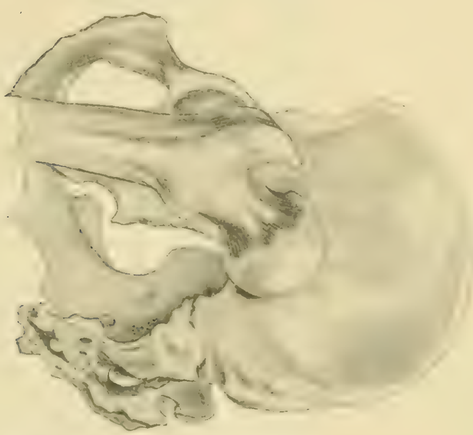


Luxation of the head of the femur onto the dorsum of the ilium.

when the flexed leg is used as a crank the head may be made to burst through the lower and posterior part of the capsule.

Allis[1] has shown that these conditions, easily demonstrated experimentally, are reproduced in many forms of accident. It is obvious that they are all favorable to a downward dislocation, and this, as is the case with the humeral head, is the direction primarily taken in the vast majority of these luxations. If the thigh has been rotated inward, either in adduction or abduction, the head of the bone will pass outward and backward and rest behind the acetabulum on some part of the outer or posterior plane of the pelvis. If it lies upon the ilium, a little above the acetabulum, it constitutes the "iliac" dislocation,—"above the obturator tendon;" if upon the ischium, on a level with or a little below the acetabulum, it is the "ischiatic" or "sciatic" dislocation, — "below the obturator tendon." This obturator internus tendon sometimes interposes an obstacle to the upward passage of the head, but its importance in this respect has been exaggerated. The degree of flexion of the limb at the time of the accident is more likely to determine the level at which the head rests.

FIG. 394.



Relation of the head of the femur to the innominate bone in dorsal luxation.

[1] Reduction of Dislocations of the Hip, Philadelphia, 1896.

In both positions the ilio-femoral ligament, which is almost invariably intact, has now become the fulcrum. As the short arm of the lever—the head and neck—has moved outward, the long arm—the shaft of the femur—must move inward; hence adduction is present in all cases of outward luxation in which the Y-ligament is not lacerated, and is persistent because the head lying in contact with the outer wall of the pelvis cannot be moved inward. Rotation inward, which is also present and persistent, is due to the same tension upon the Y-ligament. This explains the usual position of the limb with the line of the femur crossing that of the opposite thigh a little above the knee and the great toe resting upon the instep of the sound foot. Flexion of the thigh is maintained partly by the tension on the ilio-psoas.

The muscles have a very minor part in the production or maintenance of the characteristic deformity. The external rotators, the glutei and the pectineus, are often lacerated. There is shortening, and the trochanter is above the level of Nélaton's line.

In the rare cases in which the Y-ligament—or its outer limb—is torn, outward luxation with neither adduction nor inversion becomes possible.

2. *Inward or Anterior Luxations.*—These always occur with the thigh in abduction, and are favored by outward rotation, which carries the head towards the lower *anterior* part of the capsule. If it passes upward and rests on the body of the pubis, it constitutes the "pubic" luxation (Figs. 395, 396); if downward, it is in or opposite the thyroid foramen, and is often called an "obturator" or "thyroid" luxation (Figs. 397, 398). The ilio-femoral ligament again becomes the fulcrum; the short arm of the lever has been carried inward, necessitating a corresponding outward movement of the long arm; hence abduction is present. The exaggerated rotation outward is maintained by the tension of the ligament; hence the eversion of the limb. Neither abduction nor eversion can be overcome, because the head is held firmly against the pubo-ischiatic pelvic plane. The gracilis, pectineus, and adductors are apt to be torn; the stretching of the ilio-psoas, the glutei, and the muscles inserted into the greater trochanter aids in maintaining both the flexion and the eversion. The ilio-tibial band of fascia will be found relaxed; the trochanteric prominence disappears as the trochanter approaches the mid-line and is in a measure sunk in the socket. There will be shortening on measurement from the anterior superior spine to the condyle; the head of the femur will be unduly prominent in the pubic variety.

Fig. 395.

Luxation of the head of the femur onto the pubis.

With the patient in dorsal decubitus, it will be evident that the acetabula are situated on a horizontal plane about midway between the pubes and the sacrum. From this level the pelvis slopes upward to the symphysis and downward to the

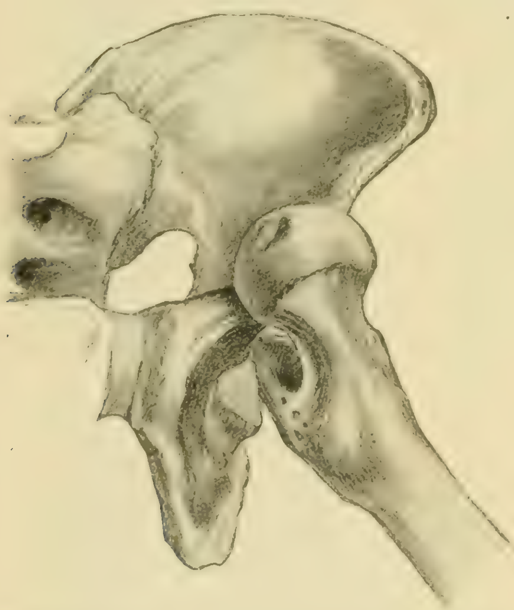
sacro-iliac junction. It is obvious that no anterior dislocation can be below the bi-acetabular line and no posterior dislocation can be above it.

As the femur is about equal in length to the tibia and tarsus, if the head is in the socket the foot will be on the acetabular level when the thigh is vertical and the knee flexed. If the head is dislocated anteriorly, the foot will be on a higher level; if posteriorly, the foot will be lower, and may even touch the surface on which the patient lies. There will be corresponding changes in the level of the knees (Allis).

The femoral vessels are not often injured in hip luxations, because they lie above the joint and luxations are always primarily downward; and because, as the head approaches them in the inward variety only, and as for the production of that variety abduction is necessary, the muscles beneath them—the pectineus and ilio-psoas—are put upon the stretch and the vessels are lifted out of harm's way.

The relations of the sciatic nerve to these injuries are of great importance. The nerve is in close relation to the hamstring muscles, especially to the biceps. These structures are made tense and are stretched across the neck of the femur posteriorly by flexion of the thigh on the pelvis, especially if the leg is also extended on the thigh, so that the origin and insertion of the hamstring muscles are separated. If, in a dislocation, the head of the femur originally lies on the anterior plane of the pelvis, and either by the force producing the displacement (as is commonly the case), by the action of muscles, or during efforts at reduction is made to pass to the posterior plane, it must traverse the narrow space between the sciatic nerve and hamstrings and the edge of the acetabulum. The nerve is thus very apt to be bruised and stretched and separated somewhat from the biceps tendon. Later, if replacement by "circumduction" is attempted, the head may pass beneath the nerve, which will then be tightly stretched over the front of the neck, will prevent full extension of the thigh, and will cause continued pain and disability. Other complications associated with the nerve may occur, and have been fully demonstrated by Allis, whose excellent experimental and clinical work forms the basis for the foregoing summary of the anatomy of hip luxations.

FIG. 396.



Relation of the head of the femur to the innominate bone in pubic luxation.

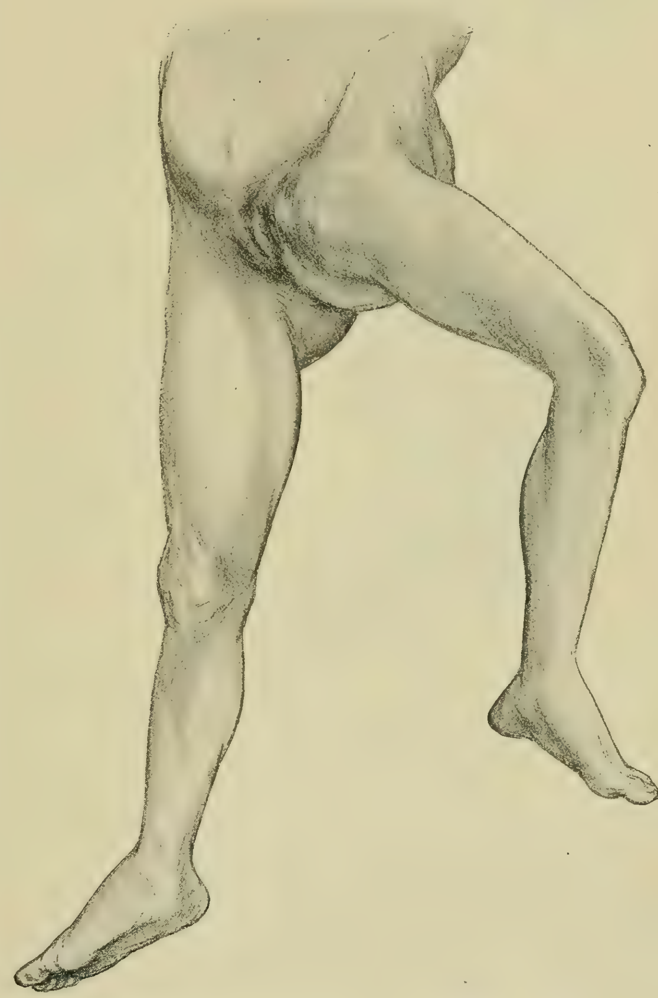
In reduction of posterior dislocations by the method of circumduction the thigh, which is already flexed, adducted, and inverted by the agencies above described, is still further *flexed* and *adducted* and lifted upward to relax the ilio-psoas and to bring the head of the bone near the margin of the acetabulum; it is then *abducted*, tightening the inner band of the ligament, and *everted*, tightening the outer band and converting the femoral attachment of the whole ligament (but chiefly of its outer limb) into a fulcrum around which, as a centre,—the abduction and eversion being continued into circumduction,—the head of the bone sweeps, skirting the lower edge of the acetabulum, and finally, by *extension* of the thigh, re-entering

that cavity at the point where it emerged. The whole movement is made up of the successive steps of flexion, adduction, abduction, eversion, and extension.

In reduction of anterior dislocations some of the steps of the procedure are reversed,—*i.e.*, the movement consists of flexion, abduction, adduction, inversion, and extension, in the order mentioned. The inner limb of the ligament is then of chief importance as a fulcrum. The objection to this method in both cases is the danger to the sciatic nerve, already pointed out, and also to the femoral vessels.

Allis's methods of reduction are intended to avoid this danger. He endeavors to cause the head to retrace accurately the path by which it left the socket. In a posterior dislocation the head has usually left the acetabulum in a downward direction, has fallen below the socket, and has passed outward around the edge of the acetabulum to its new position; the limb has then fallen into partial extension by its own weight. Thus there are three steps, which, naming them in their reverse order, are: 3, extension; 2, motion outward; 1, motion downward. The steps of his method are accordingly: 1, flexion; 2, rotation of the head inward (by carrying the leg out), placing it where it was immediately after leaving the acetabulum; 3, lifting—to bring the head to the level of the socket—and extension (using the ilio-femoral ligament, which then becomes tense, as a fulcrum, and aided by the upward pressure of the thumbs of an assistant), carrying the head upward into the socket.

FIG. 397.



Luxation of the head of the femur into the obturator foramen.

In the reduction of anterior dislocations the anatomical and mechanical principles involved are the same. In those dislocations the head has left the socket by tearing the capsule on its inner margin, and has passed inward to the pubo-ischiatic plane; the limb representing the other end of an inflexible lever must move in the opposite direction, or outward; and as it falls a little downward by its own weight, the head rises slightly. To restore it, reversing these steps, flex to a perpendicular, lowering the head somewhat; make traction on the limb, drawing the head outward; and then, the head being fixed by the hands of an assistant, adduct and extend the thigh, causing the head to enter the socket.

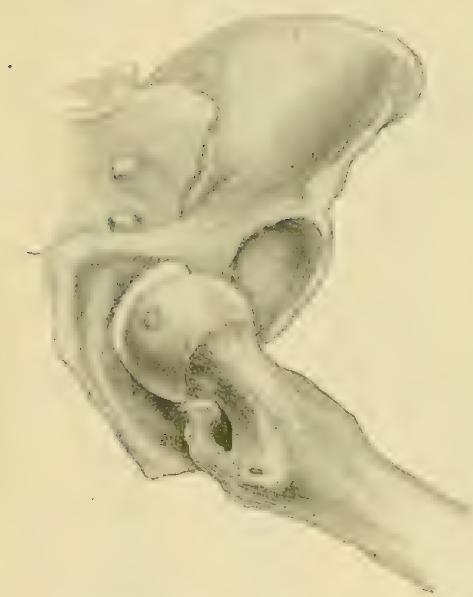
By these methods reduction of dislocation complicated with fracture of the

femur becomes possible because of the firm connection between (*a*) the base of the neck and the acetabulum through the unruptured portion of the capsule, and (*b*) the two fragments through the attachment of muscles along the linea aspera. These connections enable the limb to be used for traction, although the fracture quite precludes the employment of circumduction and rotation.

Allis summarizes the principles of his method by saying that the cardinal rule applicable to every form of dislocation of the hip is : draw the head in the direction of the socket ; apply a fulcrum at the upper part of the lever ; pry the head into the socket.

The old view that the opening in the capsule was often a slit which required enlargement before the head could be replaced has been shown (Allis and Morris) to be fallacious. The inelastic character of the capsular fibres, the globular shape of the femoral head, and the suddenness of application of the force (preventing stretching) make the rent in every case as large as the head ; it is not infrequently larger. If, however, it is situated near the femoral attachment of the capsule, it may leave a cuff of the latter hanging from its pelvic origin over the acetabulum, and offering a serious, if not insuperable, obstacle to reduction.

FIG. 398.



Relation of the head of the femur to the innominate bone in obturator luxation.

Congenital dislocation of the hip may be unilateral or bilateral, and while occasionally the result of intra-uterine traumatism, is usually due to an arrest of development of the acetabulum. The head rests on the dorsum ilii, either directly upon the bone or on the gluteus minimus. The capsule is stretched and thickened to bear the weight of the trunk. The trochanters can be seen through the glutei ; they are above Nélaton's line ; there is usually lumbar lordosis to compensate for the displacement posteriorly of the centre of gravity. The perineum is widened.

Disease of the hip-joint is frequent and grave. It may begin in the epiphysis for the head, in the synovial membrane, or, much more rarely, in the articular cartilage. It may be of any variety, but tuberculous disease outnumbers all others.

Both the frequency and the gravity of disease of the hip-joint are due to : 1, the exceptional exposure of the joint to strains or traumatism on account of its importance in carrying the weight of the trunk and in progression ; 2, the intra-capsular situation of the upper femoral epiphysis ; 3, the relation of the joint to some of the most powerful muscles of the body, so that great intra-articular pressure is easily set up and with difficulty overcome ; 4, its enclosure by dense, unyielding fibrous structures that increase tension after disease has begun ; 5, the thinness of the non-articular plate of bone that separates it from the pelvis, and the presence up to puberty of the Y-shaped cartilage which divides the acetabulum into three bony segments (Fig. 353) ; 6, its deep situation, rendering the early symptoms in many cases inconspicuous ; 7, the deprivation of fresh air and exercise, and often of sunlight, involved in the immobilization of the joint.

The disease is attended by certain symptoms having a definite anatomical basis : 1. Swelling, which is most easily demonstrated (*a*) at the lower anterior portion of the joint just internal to the ilio-femoral ligament, where the capsule is thin and the

joint is nearest the surface ; and (*b*) at the lower posterior part of the capsule, which is also thin. 2. Tenderness over these points,—*i.e.*, beneath the middle of Poupart's ligament and behind the trochanter. 3. Alteration in position, the femur being flexed, abducted, and everted. This puts the joint in the position of greatest comfort, which is that of its greatest capacity. In extension the head of the bone presses against the upper anterior portion of the capsule, and the Y-ligament is drawn as a dense band across the front of the joint. Flexion relaxes the superior or main portion of the Y-ligament and the ilio-psoas muscle ; abduction, the outer limb of the ligament and the ilio-tibial band of fascia lata ; eversion, the inner limb. Flexion is, in its effect on tension, the most effective of these motions ; eversion the least. The joint will now hold a larger quantity of fluid than when the limb is in extension. 4. At this stage, to bring the limb parallel with its fellow, to overcome the shortening caused by abduction, and to relieve strain, as the thigh cannot be moved on the pelvis, the lumbar spine is curved with the convexity towards the diseased side and the pelvis is tilted downward on that side. This is the stage of apparent lengthening. The real position of the limb in abduction is shown by straightening the pelvis so that a line drawn between the two anterior superior spines is at right angles to the longitudinal mid-line of the body. 5. With the same object of securing parallelism,—*i.e.*, of reducing strain upon the muscular and fibrous structures which are holding the limb in its abnormal position, —the deformity caused by flexion (maintained by the ilio-psoas, which is in such close relation to the front of the capsule) is met by an arching forward—lordosis—of the lumbar spine. The real position of the limb in flexion is shown by raising the thigh of the affected side until the lumbar curve is effaced and the lumbar spines touch the surface on which the patient lies. 6. Pain in the knee is often marked. It is due to the association of the nerve-supply to the two joints, both being innervated from the same spinal segments, as they both receive twigs from the anterior crural, obturator, sciatic, and sacral plexus. 7. Rigidity of the joint is due to fixation by (*a*) the muscles inserted into and passing over the capsule ; (*b*) all the muscles moving the lower limb on the pelvis. Rotation is the most valuable movement for diagnostic purposes because it is least likely to be interfered with by extra-articular disease. For example, in abscess beneath the gluteus, or in enlargement of the subgluteal bursa, flexion of the thigh is interfered with ; in psoas or iliac abscess extension is limited ; in superficial disease of the upper end of the shaft, or in suppuration of the bursa over the trochanter, adhesions of the soft parts may limit both flexion and extension. 8. Muscular wasting is often a very early symptom, and is then due to reflex atrophy from the association—emphasized long ago by Hilton—of the nerves supplying a joint with those of the muscles moving that joint ; in this instance both joint and muscles are supplied by the anterior crural, the sciatic, the sacral plexus, the obturator, etc. Later, atrophy of muscles may be due to disuse. The glutei and the thigh muscles are those most obviously affected. The atrophy of the former aids in producing the characteristic obliteration of the gluteo-femoral crease. 9. After softening of the capsule and diminution of tension have occurred, the adductors draw the limb inward. The lumbar spine is now curved so that the concavity is towards the diseased side, thereby drawing up the pelvis on that side so as to relieve strain and secure parallelism of the limb. This is the stage of apparent shortening. The real position of the limb in adduction is shown by bringing the interspinous line to a right angle with the longitudinal axis of the body. The adductors are supplied almost exclusively by the obturator nerve, which enters largely into the supply of the articulation, and act to great advantage when the capsular and ligamentous resistance has partly disappeared. As the shaft and lower end of the femur move inward, the head is necessarily brought more forcibly against the outer fibres of the capsule near its pelvic attachment, and when they soften is partially projected from the acetabulum, against the upper and outer rim of which it rests. 10. During this stage the trochanter on the diseased side is often found to be nearer the middle line of the body than the other trochanter. The cause of this is either absorption of the head and neck of the femur or deepening of the acetabulum with sinking in of the head, and the diagnosis between these may be made by rectal examina-

tion, which sometimes shows thickening over the inner surface of the acetabulum in the latter case and not in the former (Cheyne). In dislocation from disease, unless there has been separation of the head or great absorption of the neck, the trochanter will be farther away from the middle line on the affected side than on the sound one. This will serve to distinguish shortening of the limb due to this cause from shortening due to acetabular deepening. Abscesses developing within the joint may pass outward through the thin posterior part of the capsule, and under the gluteal muscles, to a point beneath the greater trochanter; they may make their exit through the cotyloid notch and point in Scarpa's triangle; they frequently pass out anteriorly, and are found beneath the tensor vaginæ femoris at the outer aspect of the thigh; they may perforate the acetabulum and point within the pelvis. A finger in the rectum may then detect fluctuation through the structures that separate the abscess from the rectal wall,—viz., the anal fascia, the levator ani, the obturator fascia and obturator internus, and the periosteum of the inner surface of the innominate bone. After perforation of the acetabulum, an abscess may extend upward and point above Poupart's ligament on the inner side of the vessels.

Excision of the hip may be done either by means of an anterior incision passing between the tensor vaginæ and sartorius muscles superficially and the glutei and rectus more deeply, or by a posterior incision in the line of the limb and just back of the greater trochanter, the muscles attached to which being divided as close to the bone as possible.

THE FRAMEWORK OF THE LEG.

This is formed by the *tibia* and the *fibula* and the *interosseous membrane* (Fig. 411). The bones are so closely united as to constitute one apparatus, but as they are separable it is necessary to describe them apart. The tibia, very much the larger, is the only one concerned in forming the knee-joint, and bears almost the whole weight. It forms the upper and inner side of the mortise known as the ankle-joint. The fibula, placed externally and posteriorly, is a slender bone. The upper end has a true joint with the tibia, the lower is more closely fastened to it. The interosseous membrane is at the bottom of a hollow between the bones. The arrangement favors lightness, as it gives increased size for the origin of muscles. The joints of the fibula, as well as its elasticity, serve to break shocks.

THE TIBIA.

The tibia consists of a shaft, an upper and a lower extremity.

The **upper extremity,** or **head,** composed of an *outer* and an *inner tuberosity*, is very large, expanding laterally from the shaft. The outline of the upper surface is transversely oval, the inner end being the broader. It is chiefly occupied by two articular surfaces for the condyles of the femur, separated at the middle by a prominence, the *spine*,[1] with a triangular non-articular surface before and behind it. The former of these is rough, the latter smooth and grooved. The *spine* itself is composed of two lateral parts connected behind, of which the inner is the longer from before backward, rising from the *condylar surfaces*. The crucial ligaments of the knee-joint are attached to the non-articular surfaces before and behind it. The *inner condylar facet* is concave; it has an oval outline and is longer from before backward than transversely. It rises as a ridge on the side of the spine. The *outer facet* is more nearly circular, being shorter than the inner. It is slightly depressed in the middle. The posterior half is usually a little convex from before backward, and is often prolonged onto the posterior surface of the bone. The convexity is much greater when the semilunar cartilage is intact. The front half may be plane, convex, or concave in the same direction. This facet rises to a point on the outer side of the spine. The **tuberosities**[2] overhang the back of the tibia. They are separated behind by the *popliteal notch*[3] continuous with the groove from the top. Under the back of the outer tuberosity is a small *articular facet* for the head of the fibula, looking downward and a little backward and outward. Its outline is uncertain, being either round or quadrilateral. It may be curved in any direction, and

[1] Eminentia iutercondyloidea. [2] Condylus lateralis et medialis. [3] Fossa intercondyloidea posterior.

its inclination varies much. In some cases it nearly or quite reaches the superior articular surface. Laterally, this tuberosity is rough for the ligaments of the knee-joint. The same may be said of the side of the inner tuberosity, which towards the back has a broad horizontal *groove* running along it for the tendon of the semi-membranosus. The *tubercle*[1] of the tibia is a triangular prominence on the front of the upper end. Its lower part is rough for the tendon of the extensor quadriceps, and its upper smooth for a bursa between this tendon and the bone. The top of the tubercle is about an inch below the top of the bone ; it is lost below in the ridge of the front of the shaft.

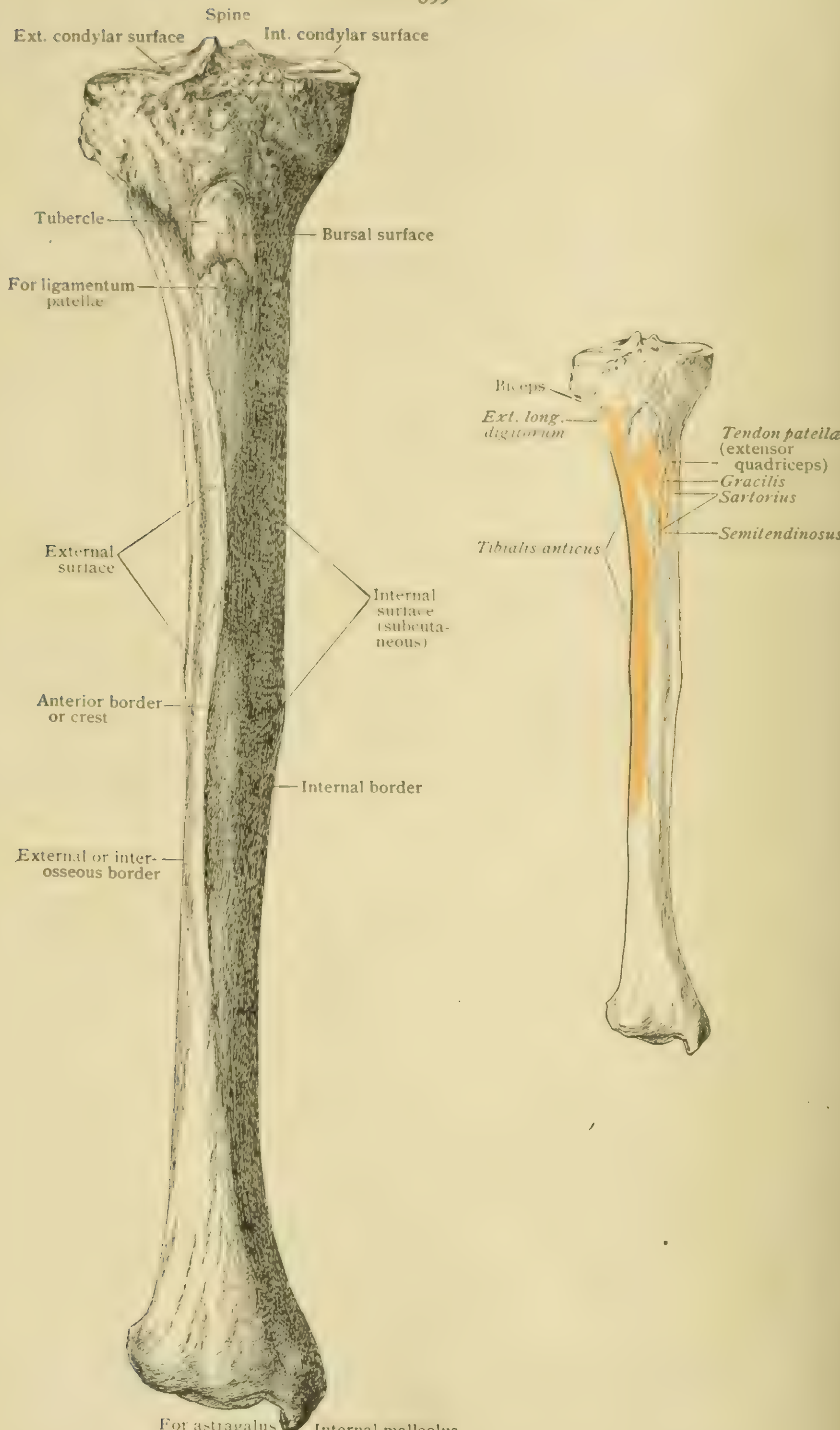
The **shaft**[2] has three borders and three surfaces. The *anterior border*, the *crest*[3] begins at the outer side of the tubercle, curves as it descends, at first a little inward, then a little the other way through the middle of the shaft, where it is very sharp, and, finally, at the lower third, becoming much less prominent, it sweeps to the front of the *inner malleolus*. The *inner border*, the least marked of the three, begins under the inner tuberosity near the back and goes to the back of the *inner malleolus*. It is most distinct in the middle. The *outer border*, or *interosseous ridge*,[4] begins below the facet for the head of the fibula, runs downward and somewhat backward past the middle of the shaft, and then, inclining forward, divides some two or three inches above the lower end into two lines enclosing a space on the outer side of the lower end, to which the fibula is bound by ligaments. The anterior of these divisions is the more evident continuation of the ridge. The *internal surface* is subcutaneous : generally convex above and concave below ; the *outer*, bounded behind by the interosseous ridge, is at first external, but in the lower third twists to the front. The *posterior*, in its upper and lower parts, faces also somewhat outward. It is crossed in the upper third by the *oblique line*,[5] which, running downward and inward from the back of the fibular facet to the inner border, marks off a triangular space above it which is occupied by the popliteus muscle. A vertical line, generally very faint, running down for some distance from the oblique line partially divides this surface into an inner broader and an outer narrower part : the former for the flexor of the toes, the latter for the tibialis posticus. The *nutrient foramen*, the largest in the body, is on this surface at the junction of the first and second thirds external to the oblique line; it runs down into the bone. The shaft is triangular on section in the upper and middle thirds, being narrower and sharper in front in the middle one. In the lower third the section becomes quadrilateral as the shaft broadens and the anterior border sinks and turns inward.

The **lower extremity** is thickest transversely. The *internal malleolus*[6] is a thick projection downward and inward from the whole of the inner side, to form one boundary of the ankle. Its lower end is thick, reaching farthest down in front, with a depression at the back for the lateral ligament of the ankle. The surface looking towards the joint is articular ; it slants a little away from the median line of the bone. The outer side of the lower end of the shaft is slightly concave, with a tubercle both before and behind. The articular cartilage of the lower end is prolonged some two or three millimetres onto this outer side. Both in front and behind, but especially in front, the bone presents a swelling, separated by a depression from the lower border, above which the capsule is inserted. On the posterior surface a broad *groove* for the tendons of the tibialis posticus and the flexor longus digitorum runs obliquely downward and inward onto and along the hind border of the malleolus. A faint *groove* for the flexor longus hallucis is sometimes seen near the outer end of the posterior surface. The lower side forms the top of the ankle-joint and is wholly articular. It is broader before than behind, as the sides converge towards the back. It is concave from before backward. There is a slight antero-posterior elevation in the middle, fitting into a depression on the top of the astragalus.

Variations.—The transverse axes of the knee- and ankle-joints are rarely parallel. The shaft of the tibia is so twisted as to make the foot point outward. The angle between the two axes varies from 0 to 48°, but is usually between 5° and 20°. The backward inclination of the top of the tibia varies considerably. When excessive, it seems to imply an aptitude for the squatting position, as among the natives of India, but no inability to assume the upright position. A continuation

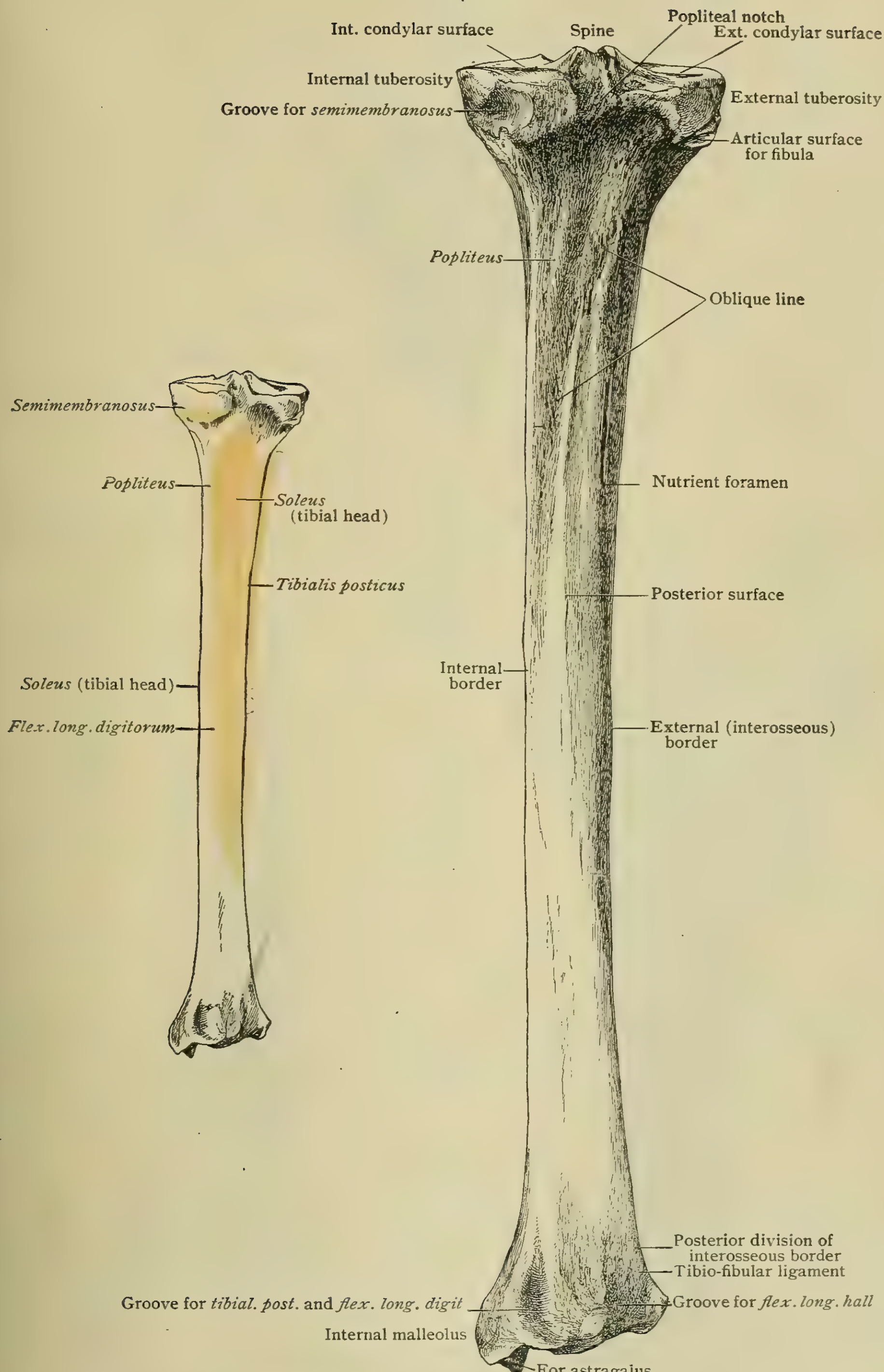
[1] Tuberositas tibiae. [2] Corpus tibiae. [3] Crista anterior. [4] Crista interossea. [5] Linea poplitea. [6] Malleolus medialis.

FIG. 399.



Right tibia from before. The outline figure shows the areas of muscular attachment

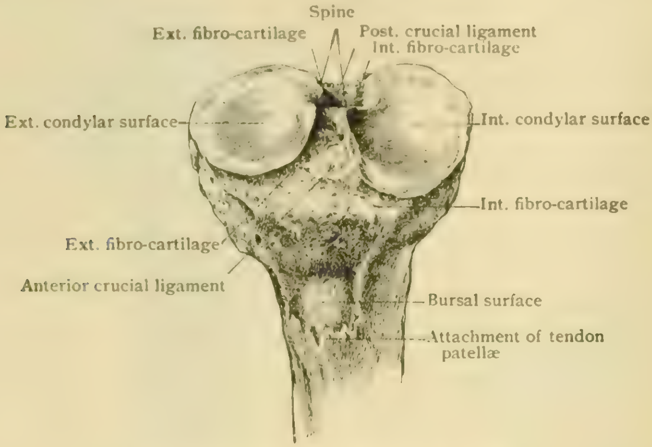
FIG. 400.



Right tibia from behind. The outline figure shows the areas of muscular attachment.

of the lower articular cartilage onto the front of the tibia, allowing extreme dorsal flexion of the ankle, is often associated with this. The thickness of the tibia is

FIG. 401.



Upper end of right tibia from above and before.

very variable. The very thin, *platycnemic*, form is most common in savage races, and is therefore associated with the pilastered femur. It is found not rarely among

FIG. 402.

Frontal section of upper end of tibia.

FIG. 403.

Frontal section of lower end of tibia.

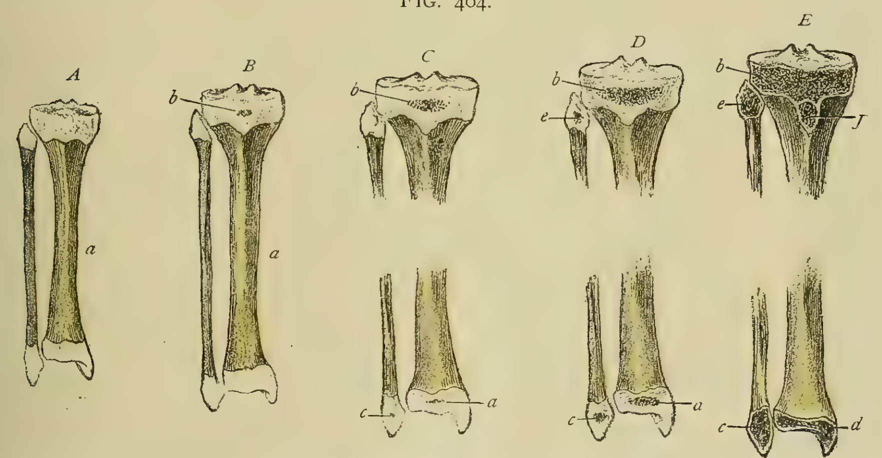
whites, but the shape of the accompanying femur is uncertain. The *tibial index* $\left(\frac{\text{transverse diameter} \times 100}{\text{antero-posterior diameter}}\right)$ is the ratio of the transverse to the antero-posterior diameter.

According to French statistics, this in whites is from 70 to 80; in savage races it is much lower. The method of reckoning it at the level of the nutrient foramen is likely to be superseded by one choosing the middle of the bone.

Structure.—The shaft has strong walls in the middle, being especially thick under the crest. At both ends the walls become thin. The head contains a large amount of cancellated tissue with comparatively thin walls. The architectural arrangement of the trabeculæ at the ends is very clear. A frontal section of the upper end shows successive vertical plates springing from the sides to support the expanding tuberosities, with an irregular system in the middle. Sagittal sections show plates from the walls meeting each other in arches. A somewhat similar pattern is seen at the lower end. In a frontal section there are several transverse plates, of which the strongest marks the border of the epiphysis. Several of these from the outer side turn down to join the lower surface at the origin of the malleolus, where there is a distinct thickening of the crust. There is sometimes an imperfect bony canal for the nutrient artery for a short distance after its entrance into the cancellated tissue.

Development.—There are only three centres of ossification: one for the shaft, appearing in the seventh or eighth fœtal week; one for the upper end, appearing usually in the last month of fœtal life; and one in the lower, appearing in the second half-year.[1] These epiphyses correspond to what has been described as the

FIG. 404.



Ossification of tibia and fibula. *A*, at eighth fœtal month; *B*, at birth; *C*, at two and one-half years; *D*, at four years; *E*, at about fifteen years. *a*, centre for shafts; *b*, for upper epiphysis of tibia; *c*, for lower epiphysis of fibula; *d*, for lower epiphysis of tibia; *e*, for upper epiphysis of fibula; *f*, for tubercle of tibia.

ends of the bone. The upper extends farthest down on the front, including the tubercle, which may have a separate nucleus. According to Rambaud and Renault, this is of usual occurrence, appearing at from eight to fourteen years and quickly joining the epiphysis. The lower end joins the shaft at about eighteen and the upper at nineteen or twenty.

PRACTICAL CONSIDERATIONS.

The upper epiphysis of the tibia is separated only by traumatism of marked severity because of: (1) its great width; (2) its irregularly cupped surface; (3) the downward projection in which the tibial tubercle is developed, or to which the latter becomes united when it arises from a separate centre; (4) the protection afforded it (*a*) on the outer side by the head of the fibula (which is connected exclusively with this epiphysis), the anterior and posterior upper tibio-fibular ligaments, and indirectly by the external lateral ligament; (*b*) on the inner side by the internal lateral ligament, and (*c*) on both sides by the fibres of insertion of the

[1] Fagerlund: loc. cit.

vasti and semimembranosus and of their fascial expansions ; (5) the toughness of the periosteum uniting it with the diaphysis ; and (6) the fact that while there is no possibility of its displacement by muscular action, it does not project enough to be exposed to the effects of direct violence. The possibility of disjunction of this epiphysis complicating an injury to the knee continues up to the twentieth year at least ; in injuries to the elbow epiphyseal separation may be excluded after the eighteenth year.

Three-fourths of the recorded cases have occurred in males, as might be expected on account of their more frequent exposure to serious injury. The epiphysis has been displaced forward, and outward and forward. It has never been displaced backward, partly, at least, on account of the tongue-like process connecting it with the tibial tubercle. Its inward displacement would necessitate the separation of the head of the fibula or the laceration of the superior tibio-fibular ligaments. The attachment of the synovial membrane of the knee-joint does not descend to the level of this epiphysis ; hence that articulation is often not involved in these injuries. They should not, when severe, be mistaken for dislocation, or, when slight, for sprains of the knee. They may be distinguished from the former by the age of the patient and the unimpaired mobility of the knee, and from the latter by the situation of the pain or tenderness. Dislocation of the knee is very rare in children.

FIG. 405.

Epiphyseal lines of tibia.

Good union has taken place in some cases ; arrest of growth has followed in others, as might be expected from the fact that the chief increase in length of the tibia takes place from this epiphysis.

The tubercle of the tibia has been detached in ten recorded instances, all males : nine from violent action of the quadriceps in powerful young men, eight of whom were between sixteen and eighteen years of age, the age of the remaining two not having been mentioned (Poland).

This separation should be carefully distinguished from fracture of the patella. In disjunction the latter bone is drawn upward, the patient is unable to extend the leg, and the swelling following laceration of the subligamentous bursa may simulate swelling of the knee-joint. The latter may be involved directly—as the synovial membrane is in close proximity to the tubercle—or indirectly, through the occasional, though rare, communication with the subligamentous bursa. Fracture of the patella, however, does not occur in children and is very rare in adolescence. In patella fracture the fragments of bone are brought together, so that crepitus may be felt only by pushing the two fragments towards each other; the groove between them can almost always be recognized. In disjunction of the tubercle crepitus can be elicited only by pulling the fragment downward ; the outline of the patella is normal, and can usually be made out. The X-rays would be conclusive. Bony union should be expected.

The shaft of the tibia gradually decreases in size to about the junction of the middle and lower thirds, and then expands again to the ankle. At its smallest point—on an average about ten centimetres (four inches) above its lower end—it has to bear a greater weight on a smaller area than any other bone (Humphry). At this level meet the two independent vertical columns into which, according to Fayel and Duret, the spongy tissue of the tibia is divided (one occupying the upper two-thirds, the other the lower third of the bone), and hence these authorities assert that this spot represents the minimum of resistance (Treves). In some tibiæ it is at or near the junction of an ill-defined long upper curve, in which the crest terminates, and a short lower curve. On transverse section the tibia is seen to be cylindrical in its lower third and three-sided above. As it has been demonstrated that if two homogeneous solids present on section equal areas, the one

triangular and the other circular, the former has the greater power of resistance (Tillaux), the shape of the tibia in this region is thought to be an additional source of weakness.

For all these reasons it is the most frequent seat of fracture from indirect violence. As in such cases the breaking strain is usually continued for a moment after the tibia gives way, the weak fibula is apt to be broken also. The line of fracture usually runs from its level on the crest upward and backward, and under the action of the calf muscles and the weight of the body the sharp lower end of the upper fragment frequently protrudes, making the fracture compound.

Fracture at about the same level from direct violence is also very common on account of the exposed position of the bone, and all fractures are apt to be compound as a result of the large proportionate area of the bone which is subcutaneous.

Fracture of the shaft at the upper end involving the knee-joint is rare, and is usually from either direct violence or a fall from a considerable height,—"compression fracture." Fracture of the lower end of the shaft involving the ankle-joint is a not infrequent complication of Pott's fracture.

FIG. 406.

Lines of fracture of tibia and fibula.

Separation of the lower epiphysis is nearly three times as frequent as that of the upper. It is caused usually by a considerable degree of violence, and in fifty per cent. of recorded cases has been associated with fracture of the lower end of the fibula or separation of the fibular epiphysis, in which case the displacement is often outward ; usually it is backward.

It may be mistaken for dislocation of the ankle. In patients from eleven to seventeen years of age disjunction of the epiphysis is more frequent than dislocation ; as the malleolus and the foot go backward with the epiphysis, the inner malleolus preserves its normal relation to the foot, but not to the leg or outer ankle. In dislocation the reverse is the case.

The ankle-joint usually escapes, as both anteriorly and posteriorly the synovial membrane is below the epiphyseal line. The synovial pouch of the lower tibio-fibular joint that extends upward between these two bones is in close relation to that line, but is separated by the periosteum which is continuous over the epiphysis, and thus also escapes injury.

Arrest of growth is not common, but has occurred, and severe ankle sprains in the young should be treated with especial care on account of the possibility of involvement of the epiphyseal joint and later disease or deformity.

Disease of the tibia, if infectious, is most common in the neighborhood of its two epiphyses and at the junction of the middle and lower thirds. The region is a favorable one for "juxta-epiphyseal sprain," in which the violence is expended on the spongy tissue of the diaphysis near the epiphyseal line. "Many of the pains called 'growing pains' are due to juxta-epiphyseal sprain or injury. Such a sprain is often nothing but the first degree of an epiphyseal separation, in the same way that an articular sprain is nothing but the first degree of dislocation" (Poland).

The usual causes—strain, traumatism, cold, etc.—influence the localization of tuberculous disease in or near the epiphyses. If recognized early, and if the infected focus is removed by operation, the knee- and ankle-joints will usually escape. In the later stages the products of liquefaction may find their way from the upper epiphyseal line to the knee-joint, either directly through the intervening half-inch of bone or by way of the tibio-fibular joint,—which is in close relation to the epiphysis (Fig. 425),—and then to the subpopliteus bursa, which always communicates with the knee-joint and often with both ; or they may gain the surface of the tibia and extend upward beneath the periosteum.

If the lower epiphysis is involved a similar direct or indirect infection of the ankle-joint may occur, the tibio-fibular synovial pouch being sometimes first involved.

Post-typhoidal periostitis and osteitis of the tibia are exceedingly common, and affect particularly the subcutaneous area of the bone near the lower third, where there are no muscular attachments. They are probably due, therefore, to slight traumatisms. This same area is peculiarly subject not only to this form of infection and, as has been said, to fracture, but also to tuberculosis (when the epiphyses are spared), to syphilitic nodes and gummata, to softening and deformity from rickets, and to sepsis spreading inward from cutaneous inflammations and ulcers. It is probably so vulnerable by reason of its exposure to frequent slight injury and to strain disproportionate to its size and strength (*vide supra*), and because of its dependent position and its distance from the main source of the blood-supply of the bone (the nutrient artery entering it at its upper third), both of which circumstances favor passive hyperæmia and the localization of infection.

Sarcoma, in accordance with the general rule already mentioned (page 366), affects chiefly the upper third of the tibia.

Landmarks.—On the inner side of the knee the internal tuberosity of the tibia is in close relation in extension with the internal condyle of the femur, the two making a uniform rounded prominence. The interval between them can be felt but not seen. If the leg is flexed and the ankle rested upon the opposite knee, the tibial tuberosity becomes visible and lies in advance of the inner condyle. The prominence of the outer tuberosity is distinctly to be seen and felt on the antero-external aspect of the limb about 2.5 centimetres (one inch) below the joint-line. It represents the lowest level of the synovial membrane. Into it is inserted, about half-way between the tip of the patella and the head of the fibula, the important ilio-tibial band of fascia to which illusion has been made in reference to fracture of the neck of the femur and dislocation of the hip (page 377).

The posterior edge of the head of the tibia is not accessible to direct examination, and this is true of the external and posterior surfaces throughout.

The internal border can be traced from the tuberosity to the malleolus. The antero-internal surface, which is subcutaneous throughout, can be seen and felt. The anterior border or crest constitutes the prominence of the "shin." It is sharp in the upper two-thirds and fades into the shaft at the summit of the lower third. In well-marked tibiæ it presents a distinct double curve, the upper part of which has its concavity outward. The tubercle is easily felt and seen. It should be in line with the ligamentum patellæ and a point on the front of the ankle midway between the malleoli. It is about on a level with the head of the fibula.

The inner malleolus is twelve millimetres (half an inch) above and in front of the outer malleolus, but on the same plane posteriorly. Its lower border is rounded. The notch for the internal lateral ligament can be felt. Its tip is twelve millimetres below the joint-line. Its sharp posterior border forms the inner boundary of the groove for the tibialis posticus tendon.

THE FIBULA.

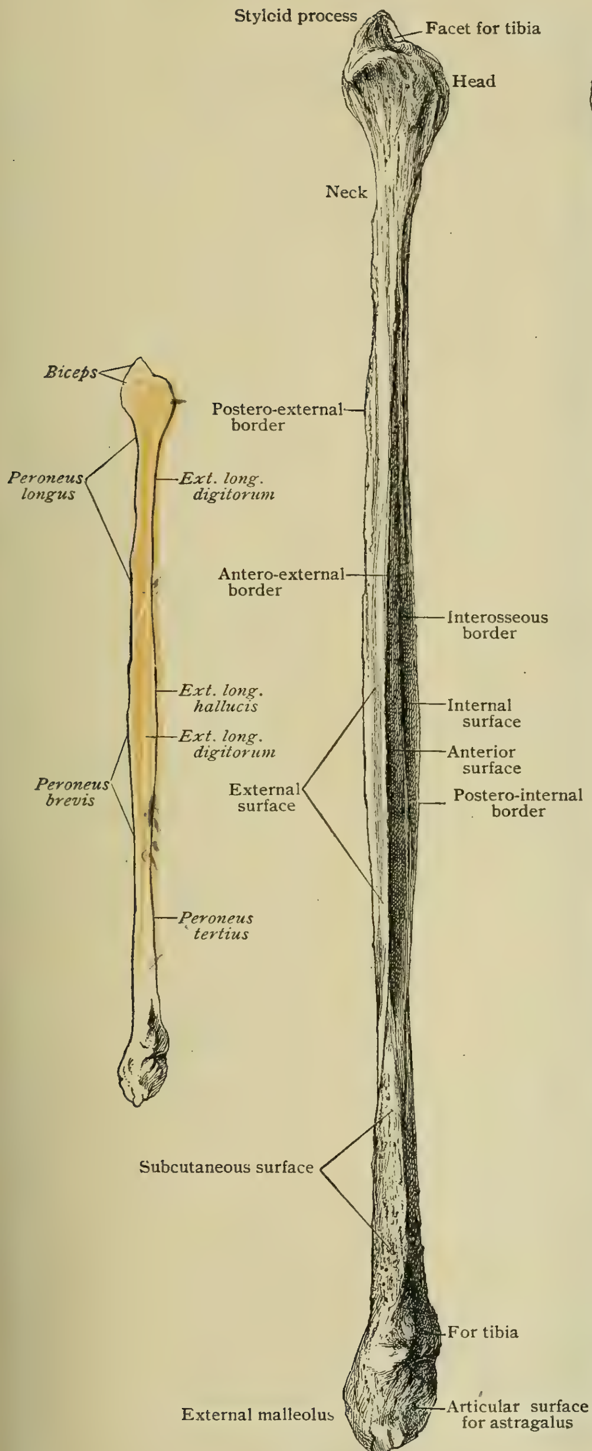
The fibula is a long, slender bone with a knob-like upper end and a pointed lower one.

The **upper extremity**, called the *head*,[1] has a rounded or vaguely quadrilateral articular surface above, looking upward, a little inward and forward, to meet the corresponding one on the tibia. The *styloid process*,[2] a short prominence, juts upward from its outer posterior angle. The outer part of the head is rough. An ill-marked *neck* below it is indistinguishable from the shaft.

The **shaft**[3] is best described as having four borders, separating four sides, though one of the borders joins another near the lower end. The **borders**, proceeding in regular order round the bone from the front, are (1) the antero-external, (2) the postero-external, (3) the postero-internal, sometimes called the *oblique ridge*, and (4) the antero-internal or interosseous. The *antero-external border* begins faintly on the front of the shaft a little below the neck, and becomes very prominent as it descends, twisting slightly outward. In the last quarter it splits into two lines which run to the front and back of the outer malleolus, enclosing a triangular subcutaneous space. The *postero-external border* begins on the outer side of the neck below the styloid

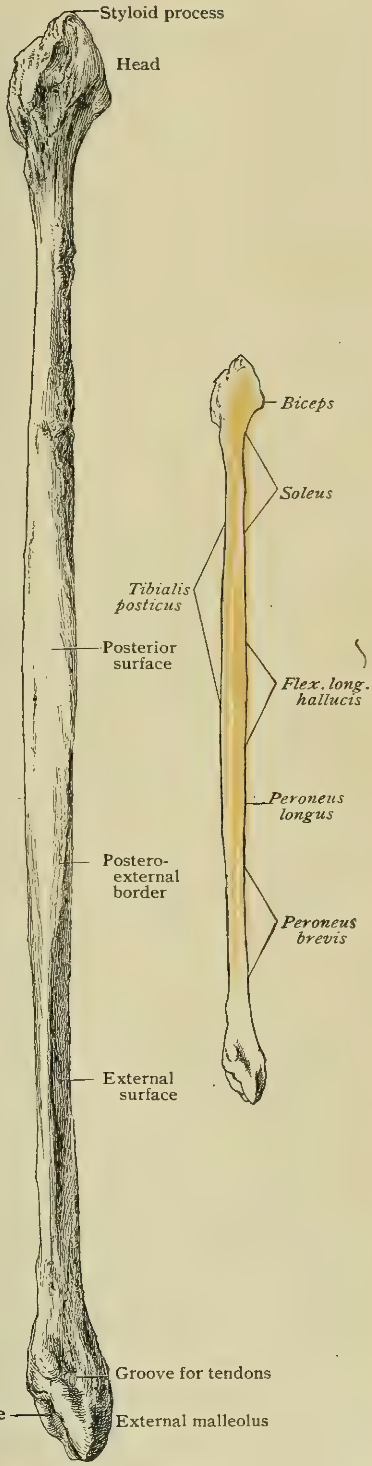
[1] Capitulum fibulae. [2] Apex capituli fibulae. [3] Corpus fibulae.

FIG. 407.



Right fibula from before.

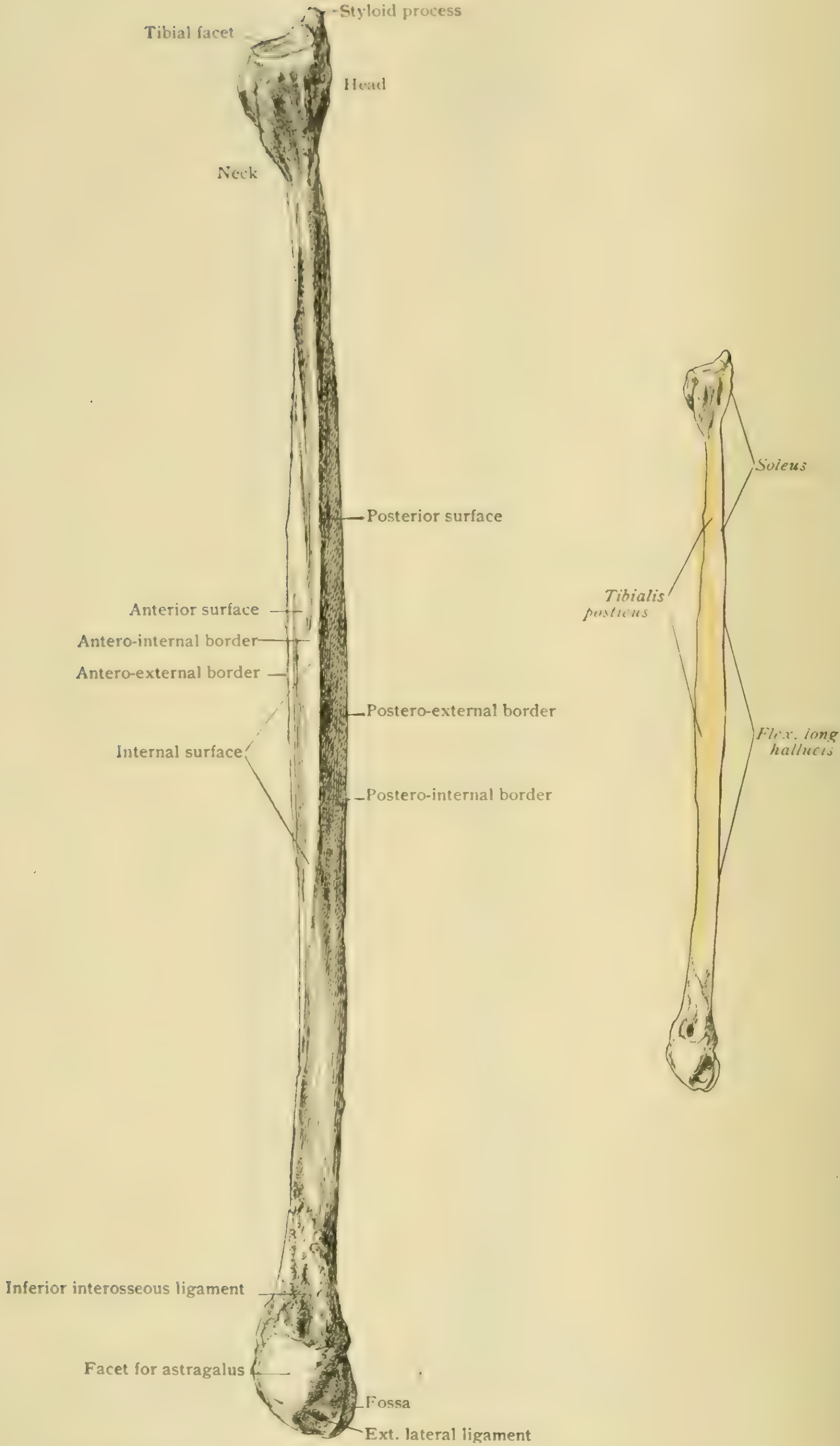
FIG. 408.



Right fibula from behind.

The outline figures show the areas of muscular attachment.

FIG. 409.



Right fibula, inner aspect. The outline figure shows the areas of muscular attachment.

process. It is strongest at and below the middle of the bone. It twists backward and is lost at the back of the malleolus. The *postero-internal border* begins at the inner side of the back of the head. It is very strong at about the middle. It ends in the last quarter by joining the *interosseous ridge*. The latter, or *antero-internal border*, begins poorly marked at the inner side of the neck, soon becomes sharp, and descends rather straighter than the others to some three inches above the lower end, where it divides into two lines which, ending at the borders of the articular facet for the astragalus, enclose a rough space for ligaments. The interosseous membrane, being attached to this ridge, separates the front of the bone from the back. The *anterior surface*, between this and the antero-external border, is very narrow. It forms a part of a hollow, of which the membrane is the floor, from which certain extensor muscles arise. The *external surface*, between the antero-external and the postero-external borders, is a characteristic one, presenting for more than the lower half a shallow groove for the peroneus longus and brevis, which sweeps down to the back of the malleolus behind the subcutaneous space enclosed by the splitting of the antero-external border. The *posterior surface* is bounded by the postero-external border and by the postero-internal till that border joins the interosseous ridge, which bounds the surface in its lower part. It faces backward above and inward below. The *nutrient foramen*, running downward, enters it rather above the middle, usually near the postero-internal border. A roughness on the outer part of this surface is for the origin of the soleus. The *internal surface*, relatively broad in the greater part of its course, looks inward to the hollow between the two bones. It ends in the last quarter where the oblique ridge joins the interosseous one.

The **lower extremity** of the fibula is pointed, forming the *outer malleolus*,[1] which projects downward and a little outward. Its outer surface is a continuation of the subcutaneous triangle, and the greatest prominence near its back is in line with the posterior of the borders of the space. Most of the internal surface is occupied by a triangular *articular facet* for the astragalus, the upper part of which is nearly vertical, while the lower slants outward. Below and behind this, on the inner side of the greatest projection, is a deep hollow for part of the external lateral ligament. The malleolus is broader behind than in front, presenting a groove in continuation of the external surface for the peroneal tendons.

Development.—The centre for the shaft appears in the eighth fœtal week; that for the head of the bone, which, according to the usual order of long bones, should develop next, does not come till after that of the malleolus. The latter appears in the second year, the former two or three years later. The lower epiphysis is probably fused with the shaft by eighteen or nineteen and the upper by twenty.

PRACTICAL CONSIDERATIONS.

The upper epiphysis has a flat lower surface and is about on a level with the most prominent part of the tibial tubercle. It includes, therefore, all that portion of the head of the fibula into which the biceps tendon and external lateral ligament are inserted. Its line of cartilage at and after the thirteenth year is in close relation with the synovial membrane of the tibio-fibular joint. Its disjunction is favored by its situation on the most exposed aspect of the limb, its subcutaneous position, and the insertion into it of the biceps muscle. The attachment of the external lateral ligament also enables a powerful strain to be brought upon it in over-adduction of the leg. In spite of these favorable circumstances, the protection afforded by the slight overhang of the external tuberosity of the tibia and the fixation given by the strong anterior and posterior upper tibio-fibular ligaments make separation of this epiphysis a very rare occurrence. Boyd says that several cases are known in which it has been pulled off by violent contraction of the biceps in an effort to prevent falling. It is then felt as an easily recognizable fragment the space between which and the diaphysis is increased upon extension of the leg.

Fracture of the shaft of the fibula in its upper two-thirds occurs from direct violence and as a secondary result of fracture of the tibia. In spite of the slenderness of the bone and its position on the outer aspect of the leg, fracture is not very frequent because of (*a*) its elasticity, which is marked; (*b*) its protective covering

[1] Malleolus lateralis.

of muscles and fascia ; and (c) its backward curvature, which carries it to a plane posterior to that of the tibia, which thus protects it both internally and anteriorly from direct violence.

Fractures about the middle of the lower third of the shaft, and especially those about 7.5 centimetres (three inches) from the ankle, are so commonly produced by leverage that, whatever their exact level, most of them may be grouped as instances of Pott's fracture, although an effort has been made to draw between them distinctions that are ordinarily academic rather than practical.

These fractures usually result from over-abduction of the foot. When that occurs suddenly, the weight of the body being upon the limb, the tension first comes upon the deltoid ligament. This may stretch slightly or some of its fibres may be torn, or there may be a small detachment from its malleolar origin. As a rule, such a case ends in a more or less severe sprain. If the ligament ruptures, or the tip of the malleolus is torn off, or the malleolus itself is fractured, the abduction of the foot continues, and the astragalus is subluxated and carried against the inner surface of the external malleolus. The fibula is thus converted into a lever of the first order. The force is applied at its lower end ; the fulcrum consists of the stout tibio-fibular ligaments, which are often stronger than the bone itself and which are rarely completely ruptured, though often stretched and lacerated ; the weight or resistance is in the body of the bone, which is prevented from moving inward by the articulation of its upper end with the tibia. As soon, therefore, as its limit of elasticity is exceeded, it breaks at a weak (if not its weakest) point, and the upper end of the lever—*i.e.*, of the lower fragment—is forced in the direction opposite to that of the lower end,—*i.e.*, the malleolus (Fig. 410). The impact of the astragalus and the pull of the ligaments may cause, in addition to the fracture of the tip of the malleolus, fracture of the anterior or of the outer articular edge of the tibia. If the tibio-fibular ligaments rupture, the fibula becomes a lever of the second order, the fulcrum shifting to its upper end. The dislocation of the astragalus outward will be more marked. The bone may break at any point, but the fracture is still likely to be within the limits of the lower third.

Rose and Carless have adopted the following useful classification based on the injury to the inner side of the foot or to the tibia itself. It divides these fractures into four groups, the term Pott's fracture being correctly applied, according to these authors, to the first two only. 1. The internal lateral ligament is torn through ; the intact internal malleolus can be felt projecting beneath the skin (Fig. 410, *A*). 2. The malleolus is torn off and a distinct sulcus can be felt between it and the lower end of the tibial shaft (Fig. 410, *B*). 3. The interosseous tibio-fibular ligament is ruptured (or the flake of bone at the tibial attachment is torn off) ; the subluxation outward is very marked ; either the inner malleolus or the deltoid ligament yields,—"Dupuytren's fracture" (Fig. 410, *C*). 4. The tibia fractures transversely just above the base of the malleolus ; the lower end of the upper fragment may be mistaken for the tip of the malleolus (Fig. 410, *D*).

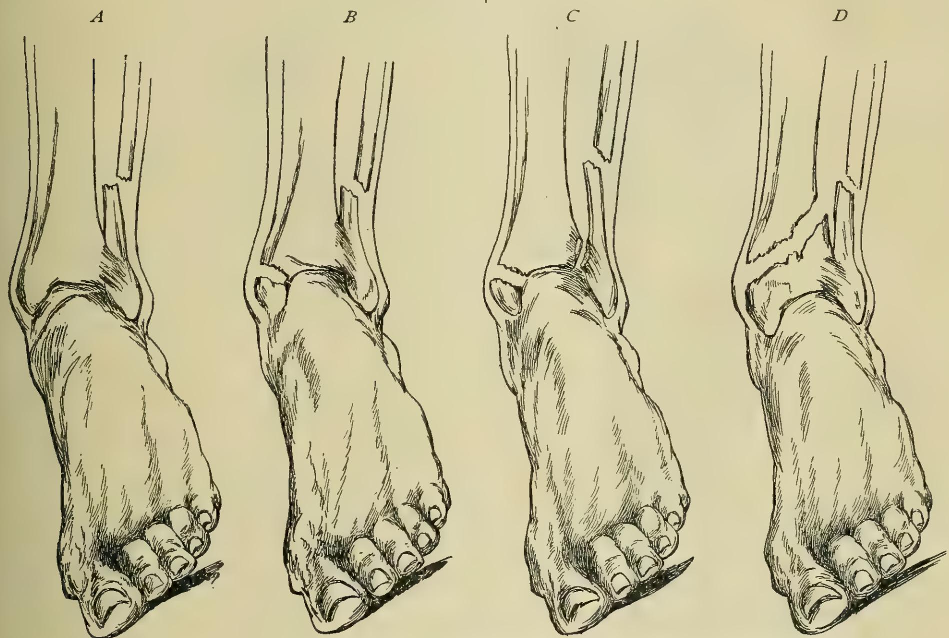
The less frequent accident of forcible over-inversion of the foot, if the external lateral ligament holds, produces by the same mechanism a similar series of occurrences. The tip of the external malleolus is dragged violently inward, the tibio-fibular ligaments act again as a fulcrum, and the bone is apt to break at about the same level,—*i.e.*, from 5 to 7.5 centimetres (two to three inches) above the joint,—the upper end of the lower fragment being carried outward instead of inward. In these cases there is a subluxation of the astragalus inward which not infrequently results in a fracture of the inner malleolus. In all these forms of fracture the laceration of ligamentous structures loosening the connection of the foot to the leg, the upward pull of the calf muscles, and the weight of the foot itself combine to produce a subluxation of the foot backward which is often overlooked.

The cardinal symptoms of the common form of Pott's fracture are eversion of the foot, prominence of the inner malleolus, shortening of the distance from the front of the ankle to the web of the great toe, increased width between the malleoli, and tenderness over (*a*) the space between the tibia and the external malleolus anteriorly,—*i.e.*, over the strained or torn tibio-fibular ligaments ; (*b*) over the base or tip or anterior border of the internal malleolus,—*i.e.*, over a ruptured internal lateral

ligament or a fracture of the malleolus; and (*c*) over the fibula from two to four inches above the tip of the malleolus,—*i.e.*, over the fibular fracture.

The lower epiphysis of the fibula is an exception to the rule that the epiphyses of long bones appear first at the end from which the nutrient artery is directed, and to the more important rule that the chief growth of the long bones takes place at the end where the epiphysis is last united to the shaft; in the other long bones this is also the end *from* which the nutrient artery is directed. We have seen that in the upper extremity, the nutrient canals being directed towards the elbow, the epiphyses at the upper end of the humerus and the lower ends of the radius and ulna appear earlier and join the shaft later than those at the elbow, and that thus it is from the shoulder and wrist that the chief growth of the upper limb takes place. In the lower extremity, the nutrient canals being directed towards the hip and the ankle, the lower epiphysis of the femur and the upper epiphysis of the tibia appear first and are joined on last, and the chief growth of the lower limb takes place at the knee.

FIG. 410.



Showing four types of fracture of lower end of fibula according to classification of Rose and Carless.

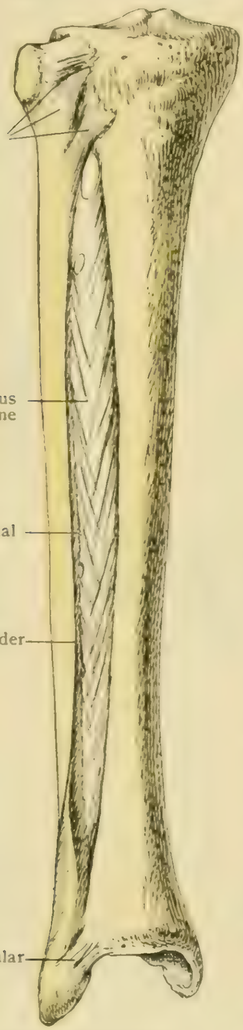
In the case of the fibula—the upper part of which is in man in a comparatively rudimentary condition (Poland)—the exception is noted to avoid confusion in the mind of the student. The nutrient artery runs downward, but the lower epiphysis is both the first to appear and the first to consolidate, and is the chief seat of growth. It is not of great practical importance, although it is probable that in most so-called fractures of the extreme lower end of the fibula occurring between the twelfth and nineteenth years there has been a disjunction of this epiphysis. The solution of continuity would then be below instead of above the tibio-fibular ligaments.

The synovial membrane of the ankle-joint is attached above the epiphyseal line, and that articulation is therefore likely to be involved more frequently than in fractures of the diaphysis. This fact, together with the importance of the epiphysis in its relation to growth of the bone, should cause the possibility of its disjunction to be borne in mind. If arrest of growth does ensue, a condition of talipes valgus may result from the relative overgrowth of the tibia. For the relief of this the operation of "conjugal chondrectomy"—removal of the lower epiphyseal cartilage of the tibia—has been suggested. This at twelve years of age is seventeen millimetres from the tip of the malleolus. It is subcutaneous.

Sarcoma of the fibula attacks the upper end in the great majority of cases. Osteophytes are not infrequent upon the median margin of the shaft above the lower end.

Landmarks.—In extension of the leg the position of the head of the fibula is indicated by a depression on the posterior part of the outer surface of the leg a little below the level of the tibial tubercle, corresponding to the interval between the tendon of the biceps above and the peroneus longus below. The head is subcutaneous and may be distinctly felt there. In flexion it projects above the surrounding surfaces and may be seen. The insertion of the biceps may show as a rounded prominence at the base of the styloid process. The synovial membrane of the knee descends to a point just above the upper level of the head. The upper half of the fibula is so covered by muscles that its outline cannot be recognized distinctly by palpation. In the lower half it may be felt through the muscles. Its lower fifth lies between the tendons of the peroneus tertius and those of the peroneus longus and peroneus brevis, and is subcutaneous, as is the malleolus. The relation of the plane of the shaft to that of the tibia should be remembered, as should the plane of the external to that of the internal malleolus (page 390). The tip of the external malleolus is from twelve to eighteen millimetres (one-half to three-quarters of an inch) nearer to the heel than that of the internal malleolus. The whole malleolus, viewed from without inward, is in the mid-line (antero-posteriorly) of the ankle-joint. It becomes abnormally prominent in cases of atrophy of the peroneal muscles, particularly of the peroneus longus.

FIG. 411.



Tibio-fibular ligaments from before.

CONNECTIONS OF THE TIBIA AND FIBULA.

These are the superior and inferior joints and the interosseous membrane.

The Superior Tibio-Fibular Articulation[1] (Fig. 411).—The cartilage-covered articular surfaces already described vary greatly both in direction and in the nature of their curves. Perhaps the more ordinary arrangement is for the tibial facet to be concave in a horizontal and convex in a vertical plane ; but the converse may occur, and there are many intermediate forms. The *synovial sac* extends upward behind and may communicate with the knee-joint. The *capsule* is very strong, except below, and especially so at the outer side where the *long external lateral ligament* of the knee is incorporated with it. The *anterior* and *posterior superior tibio-fibular ligaments*[2] are strong fibres, strengthening the capsule and passing outward and slightly downward from the tibia to the fibula.

The **interosseus membrane**[3] (Fig. 411) extends from the head of the fibula down along the interosseous ridges of both bones till these split. Its fibres run in the main downward and outward, but in the upper part many run downward and inward. There is a large opening at the top above the membrane or through it.

The Inferior Tibio-Fibular Articulation[4] (Fig. 411).—This joint is essen-

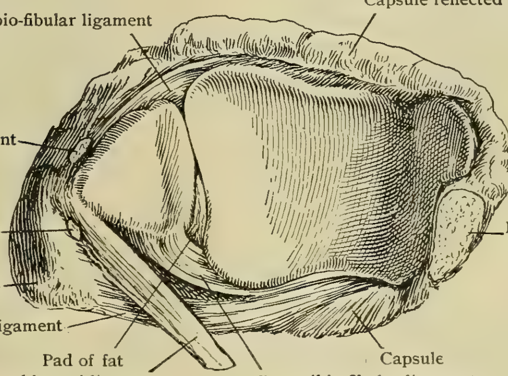
[1] Articulatio tibiofibularis. [2] Ligg. capituli fibulae anterius et posterius [3] Memb. interossea cruris. [4] Syndesmosis tibiofibulare.

tially ligamentous, though the articular cartilage of the ankle-joint extends for a few millimetres onto the opposed sides of each bone.

The **inferior ligaments** are the *interosseous*, the *anterior* and *posterior*, and the *transverse*. The *interosseous ligament* is a thickened continuation of the membrane, consisting of short fibres connecting the rough surfaces bounded by the splitting of the interosseous ridges.

The *anterior* and *posterior ligaments*[1] (Fig. 411, 412) are strong bands situated respectively on the front and the back of the tibia and running downward and outward to the fibula. The anterior deepens the socket but slightly, while the posterior, reaching nearly half-way down to the malleolus, makes a considerable addition to the back of the joint. The *transverse ligament* (Fig. 412) containing

FIG. 412.



Socket of right ankle-joint from below.

probably elastic fibres, runs obliquely from the back of the lower border of the tibia to the tip of the outer malleolus. It projects into the joint, the capsule forming a pouch between it and the posterior tibio-fibular ligament. It is closely connected at the fibula with the posterior fibulo-astragaloid ligament. The two have the appearance of diverging bundles of the same structure. The *synovial cavity* is prolonged some three millimetres upward between the bones. The back part of the crack between the bones is concealed by a pad of fat (Fig. 412) covered by synovial membrane projecting into the joint. It advances or recedes between the bones according to changes of position.

Movements.—The motions between the tibia and the fibula are slight and not very definite. The head of the fibula may play a little forward and backward, and the bone may rotate on its long axis. These motions are resisted alternately by the anterior and posterior ligaments at both ends.

THE BONES OF THE LEG AS ONE APPARATUS.

Surface Anatomy.—The upper part of this support consists of the head of the tibia with that of the fibula well back on the outer side. The framework narrows to the junction of the middle and lower thirds, where the tibia is nearly at its smallest and seems to bend towards the fibula. Below this it broadens for the socket of the ankle. The fibula in the lower third is close to the tibia and no longer so much behind it, which is due in part to the subsidence of the crest of the tibia. The difference of relations is shown by sections at three levels (Fig. 413). The whole apparatus is described as having three borders and three surfaces. As the details have been given with the bones, the chief features only are here enumerated. The *anterior border* is the *crest* of the tibia; the *posterior and internal border* is the posterior border of the same bone; between them is the subcutaneous internal surface. The *posterior and external border* is the postero-external border of the fibula. Thus there remain an antero-external and a posterior surface, each of which is formed in

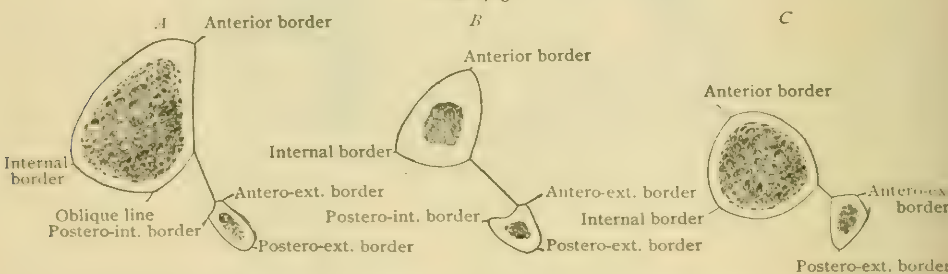
[1] Ligg. malleoli lateralis anterius et posterius.

part by the interosseous membrane. The *antero-external surface* presents the following features: (1) a large surface of the tibia, looking outward as far as the lower third and then forward; (2) the interosseous membrane; (3) a narrow[1] surface of the fibula, bounding externally the fossa of the front of the leg, shallow above, deep and narrow below; (4) the antero-external border of the fibula, splitting below to enclose the subcutaneous surface above the outer malleolus; (5) the grooved surface of the fibula occupied by the peronei.

The *posterior surface* presents, continuing in the same course: (1) the posterior surface of the fibula, looking backward above, inward below; (2) the postero-internal border, ending in the interosseous ridge; in the upper two-thirds this overhangs a deep hollow; (3) the internal surface, which ends below with the preceding border; (4) the interosseous membrane; (5) the posterior surface of the tibia. The interosseous membrane is at the bottom of a much deeper gutter than in front, which also becomes very narrow below.

The outward twist of the ankle has been mentioned, and it has been shown that this depends on the twist of the tibia. It is to be noticed that while the antero-external, the postero-external, and the postero-internal borders of the fibula run as if

FIG. 413.



Sections across the bones of right leg, showing their relations at different levels; seen from above. *A*, near head of fibula; *B*, near the middle; *C*, a little above the ankle.

the lower end of that bone had been twisted outward, the same is not true of the borders and surfaces of the tibia. On the contrary, the crest, with the surface on each side of it, slants in the lower half of the leg downward and inward. It is as if these borders of both bones had been twisted away from the median line of the leg, one to each side, and that the interosseous ridge had stayed straight. There seems to be no relation between the degree of forward bend of the neck of the femur and the outward twist of the socket of the ankle. Probably both have an influence on the direction of the foot, but it depends chiefly on the latter. It is unwarranted, therefore, to expect all children to turn out the toes alike. The whole of the front and sides of the head of the tibia is easily felt, but it is thickly covered behind. The top of the tuberosities is clear on either side, and in front the whole of the tubercle can be explored when the tendon is relaxed. The head of the fibula is distinct far back on the outer side. Descending the leg, it is easy to follow the sharp crest of the tibia into the lower third, and the internal subcutaneous surface down to the malleolus. The external surface, where it becomes anterior above the ankle, is plain in spite of the tendons crossing it. The shaft of the fibula is so covered with muscles that little more than its general position is to be made out above the triangular subcutaneous surface over the outer malleolus, which latter is also easily explored. The relations of the malleoli are considered with the foot (page 449).

THE PATELLA.

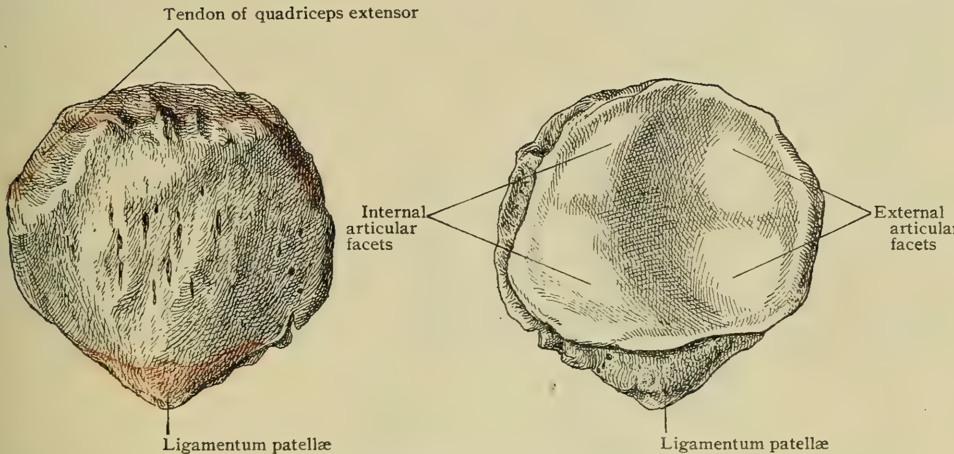
The knee-pan, the largest sesamoid bone, is triangular or shield-shaped. The **anterior surface** is covered by the tendinous fibres of the quadriceps, which replace the periosteum and mark the surface with longitudinal lines. Jagged spines from the ossification of the tendon are often found at the top. The transverse

[1] In the transverse sections (Fig. 413) this surface is exceptionally small.

diameter is usually rather larger than the vertical, especially in strong, and consequently in male, bones.

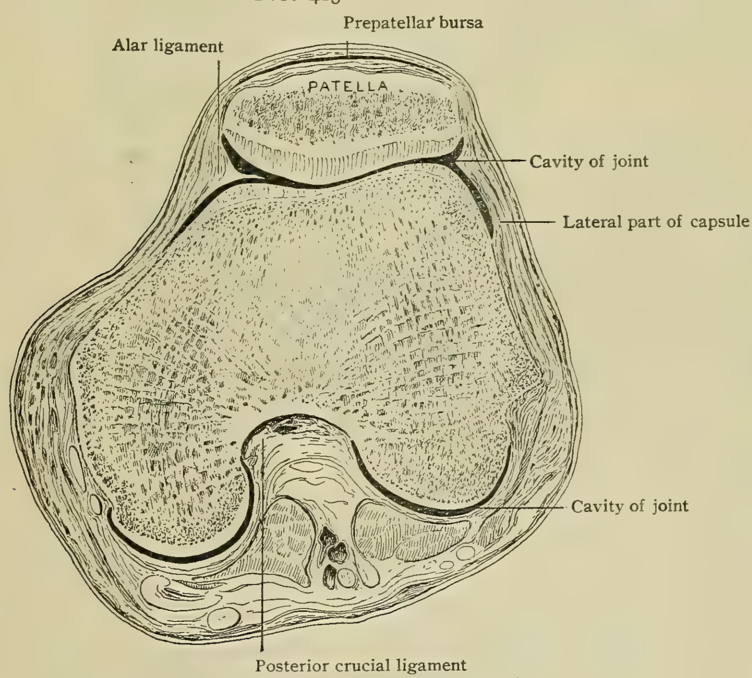
The *base*[1] is above with a slightly curved outline, and the *apex*[2] below, usually somewhat internal to the middle. The outer lower border is more oblique than the inner. The **posterior surface** is divided into an upper articular part and a much smaller non-articular one below, in which the bone is thinner at the expense of the posterior surface and is covered by the fibres of the ligamentum patellæ. The upper part, covered with articular cartilage and forming a part of the knee-joint, is

FIG. 414.



Right patella, anterior and posterior surfaces.

FIG. 415



Horizontal frozen section through right knee-joint.

[1] Basis patellae. [2] Apex patellae. [3] Facies articularis.

much broader transversely than vertically. The outer three-fifths or so, which plays on the external condyle, is concave transversely and the inner two-fifths convex. The convexity begins with a vertical prominence which marks the greatest thickness of the bone and appears to divide the hind surface into two parts, as a horizontal section shows, the surface receding from it on either side. Nevertheless, the whole inner part is convex, as described. Vertically, both sides are slightly concave. A close examination of a fresh specimen shows, what rarely is to be seen on the dry bone, that the articular surface is to be further subdivided. A narrow vertical facet is seen along the inner side, constituting a surface which rests on the edge of the inner condyle in extreme flexion. The rest of the articular surface is divided into three horizontal zones, one above another, by two transverse lines. The top of the bone is very thick, most of it being occupied by the insertion of the rectus. The capsule of the knee-joint is inserted all around the articular surface some two or three millimetres from its edge, so that a little of the border is enclosed in the joint. Several nutrient foramina are found on the anterior surface.

Development.—The patella appears as a cartilaginous point in the course of the third fœtal month. Ossification begins by the deposit of several granules some time between two and five years. These soon unite into a central mass, from which ossification spreads, more rapidly, however, in the deeper parts. The bone is not fully formed till after puberty, perhaps not before eighteen.

THE LIGAMENTUM PATELLÆ.

This name is applied to the tendon of the quadriceps extensor muscle, in which the patella is a sesamoid bone (Fig. 416). It is a strong, flattened, fibrous band some two inches long. Just below the knee-pan it is at least one and one-quarter inches broad, but at its insertion into the front of the upper part of the tuberosity of the tibia its breadth is not over one inch. The line of insertion is oblique, the outer end being the lower. Just above the insertion a synovial bursa lies between the tendon and the bone. A mass of fat above the bursa separates the tendon from the capsule. The tendon is fused at the sides with fibrous expansions from the quadriceps.

THE KNEE-JOINT.

This is a compound joint between the femur and the tibia, the patella being a sesamoid bone in the tendon of the extensor of the leg, incorporated in the front of the capsule. The patella is in relation to the femur only, and sometimes it is convenient to consider the knee-joint as the sum of three distinct ones,—namely, that between femur and patella, and one for each condyle with the tibia. The joint is enclosed by a capsule partially subdivided in many ways. Fibro-cartilaginous disks, the semilunar cartilages on the top of the tibia, tend to subdivide the joint below each condyle into an upper and a lower half. The crucial ligaments nearly cut off communication between the parts of the joint under each condyle. The mucous ligament assists in this, and with the alar ligaments tends to isolate the patella.

Discussion of the knee-joint calls for the description of the following component structures :

The Capsule and its Accessories.

The Semilunar Cartilages and their Accessories.

The Crucial Ligaments.

The Subpatellar Fat with the Ligamentum Mucosum and the Ligamenta Alaria.

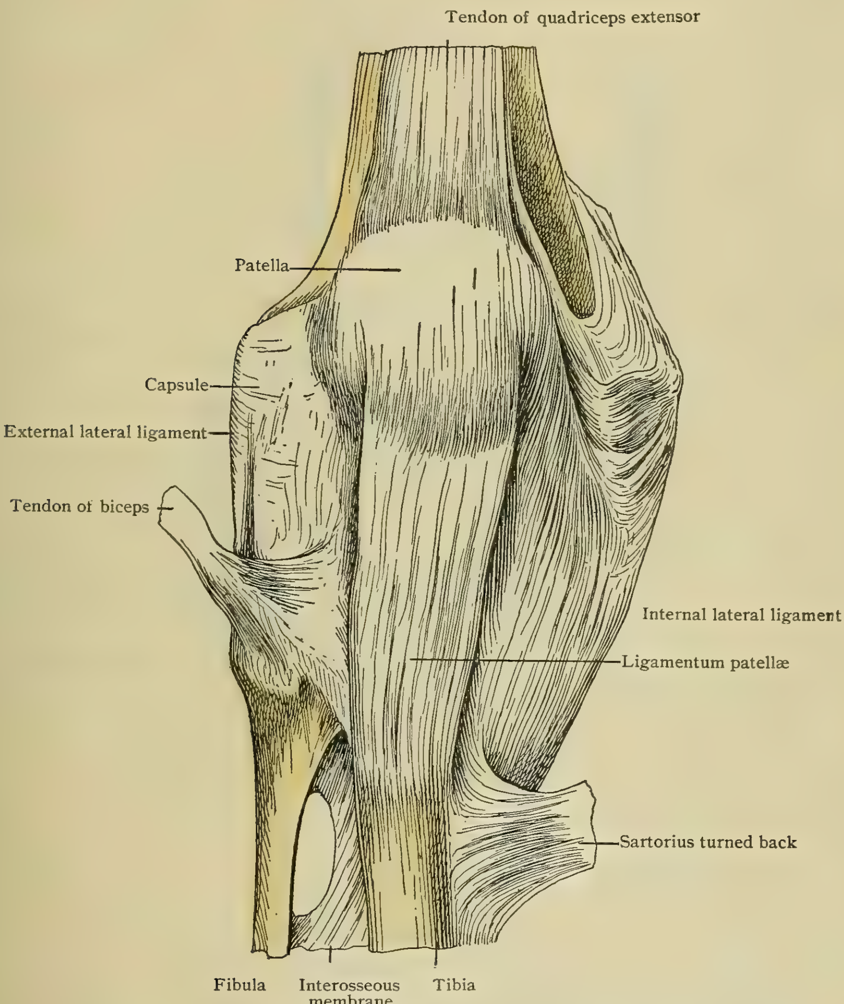
The Synovial Membrane.

Certain Bursæ.

The **capsule** (Fig. 416) arises from the femur, mingling with the periosteum, a little above the anterior articular surface ; from the sides of the condyles as high as the level of the lateral tuberosities ; from the back one centimetre beyond the highest point that the cartilage reaches on the top of the condyles ; and from a slightly lower level above the intercondyloid notch. It is attached in front around the articular surface of the knee-pan and inferiorly to the tibia all around, but a

little below the top; for the articular cartilage is continued over the border onto the sides. It is lower at the back of the outer tuberosity, where the joint sometimes joins that of the head of the fibula. It is attached to the periphery of the semilunar cartilages. This, which is the capsule proper, is very much strengthened by surrounding structures. On each side a strong fibrous layer passes from the condyles to the patella (*ailerons de la rotule* of French authors) (Fig. 418). Superficial to this, and not adherent to it, come the aponeurotic fibres of the vasti, and still more superficially the fascia lata. They fuse with the capsule at the sides of

FIG. 416.

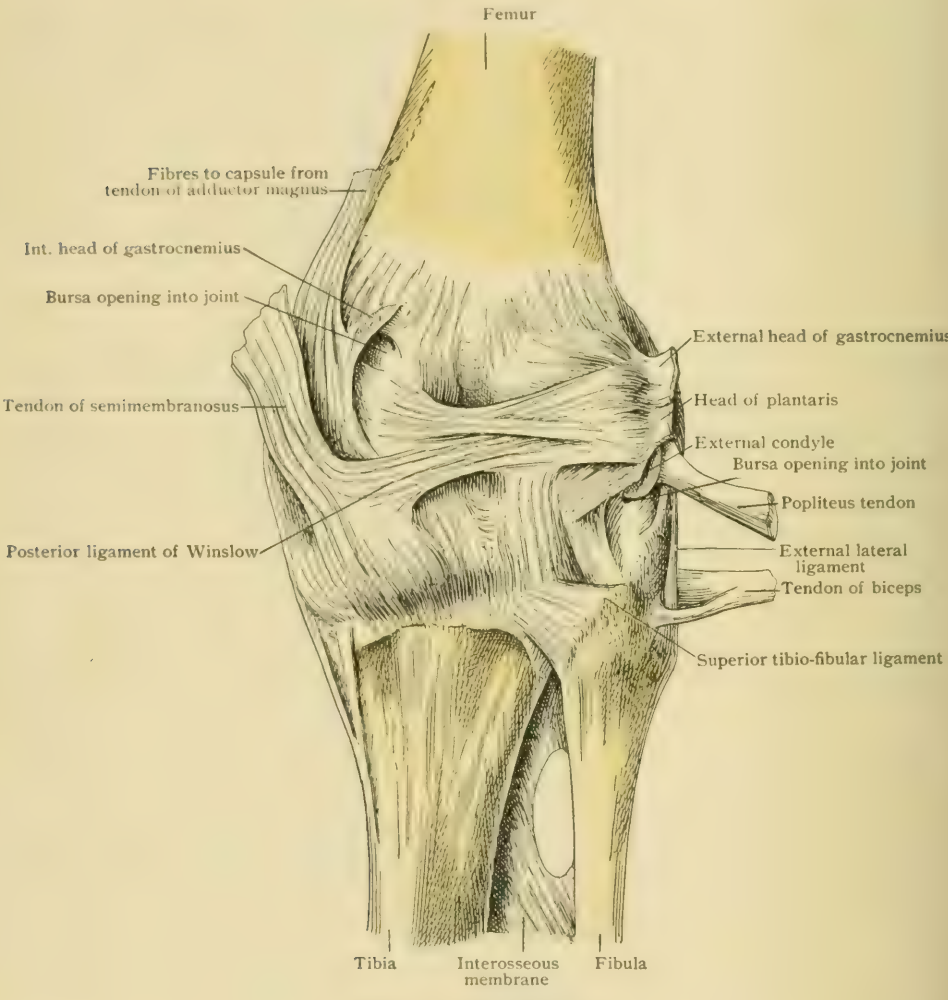


Right knee-joint from before.

the patella, but extend over the latter in two tolerably distinct layers. Both heads of the gastrocnemius and the plantaris are to a great extent incorporated with the capsule behind (Fig. 417). The tendon of the semimembranosus, which has its chief insertion in the groove in the inner side of the tibia where it is covered by the more superficial lateral fibres of the capsule, sends across the back of the capsule strong transverse diverging fibres, known as the **ligament of Winslow**, some of which are directly continuous with the outer head of the gastrocnemius (Fig. 417). Some longitudinal fibres near the back of the inner side, only artificially separable

from the rest, have been called the **internal lateral ligament**[1] (Fig. 416). The **long external lateral ligament**[2] (Fig. 418), though connected with the capsule by areolar tissue on its deep surface, is truly a distinct ligament. It arises from the external tuberosity of the femur and runs as a flattened cord downward and somewhat backward to the outer surface of the head of the fibula, almost, or quite, splitting the tendon of the biceps, which is inserted external to it, overlapping the ligament in front and behind. A *shorter band* placed more posteriorly and inseparable from the capsule can often be traced to the styloid process. The tendon of the

FIG. 417.



Right knee-joint from behind.

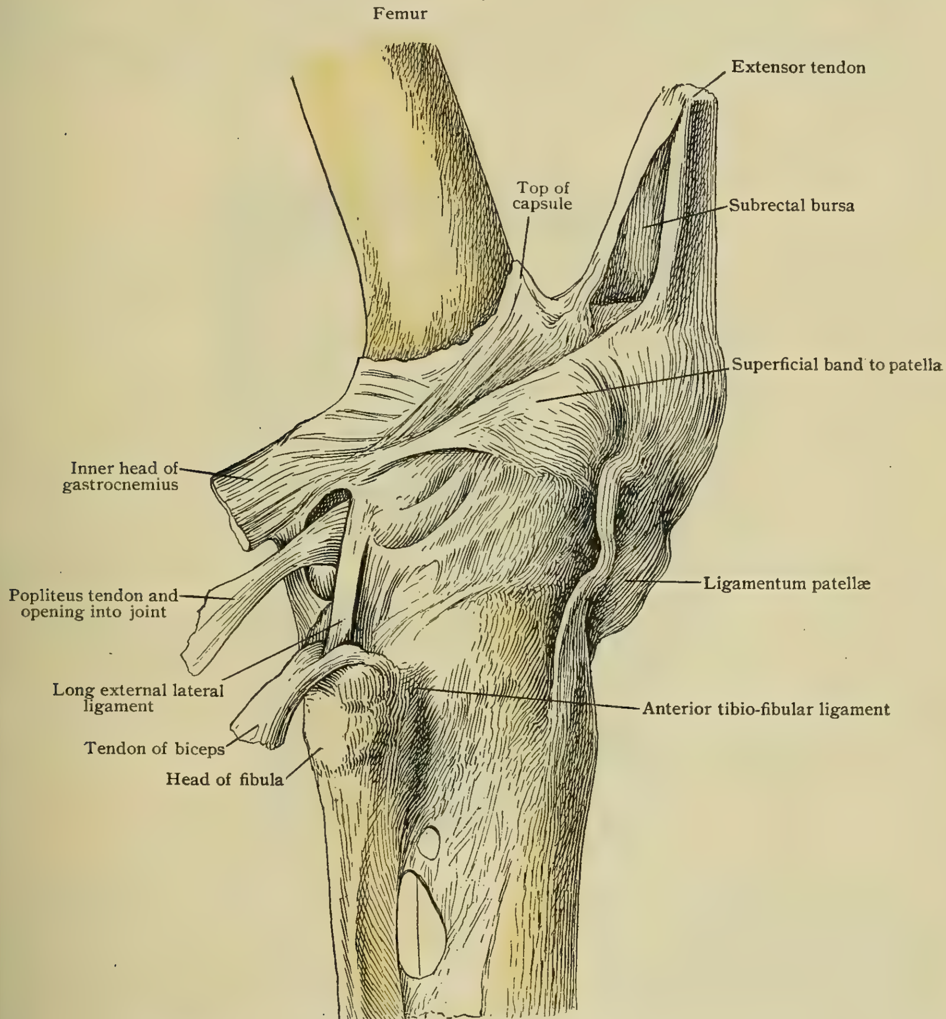
popliteus entering the joint from behind is incorporated with the capsule beneath the long external lateral ligament, as described with the bursæ.

The **semilunar cartilages** (Figs. 419, 420) are two crescentic disks of fibrocartilage lying each on top of one of the tuberosities of the tibia, with their thick outer borders at the periphery attached to the capsule and their thin edges free, so as partially to divide the joint into an upper and a lower part. The pointed ends (*cornua*) are fastened near the middle line of the joint. Those of the **external cartilage**[3] are attached to the front and back of the fibular facet of the spine of the tibia and to the inner border of the raised articular facet before and behind it. The

[1] Lig. collaterale tibiale. [2] Lig. collaterale fibulare. [3] Meniscus lateralis.

posterior horn, moreover, joins the posterior crucial ligament. There is not more than one centimetre between the two horns, so that this cartilage is almost circular. The **internal cartilage**[1] is C-shaped. The anterior horn, thin and fibrous, is inserted into the rough surface near the anterior border at no very definite point. Sometimes it runs into the transverse ligament without any fixed ending; sometimes the extreme point is free. The posterior horn is attached to the back of the tibial facet of the spine and to the edge of the articular facet behind it. The

FIG. 418.



Right knee-joint, external aspect. The extensor tendon is drawn forward and upward.

distance between the horns is about three centimetres. The anterior horn of the internal cartilage may not come into contact with the femur. The vertical diameter of the cartilages at the periphery is from six to eight millimetres. The breadth varies in different joints, ranging from one to nearly two centimetres.[2] The broadest part is near the back of the internal one, but the external is, on the whole, the broader. It is said sometimes to completely divide that half of the joint. The free border is very thin and may present fine prolongations with scalloped edges.

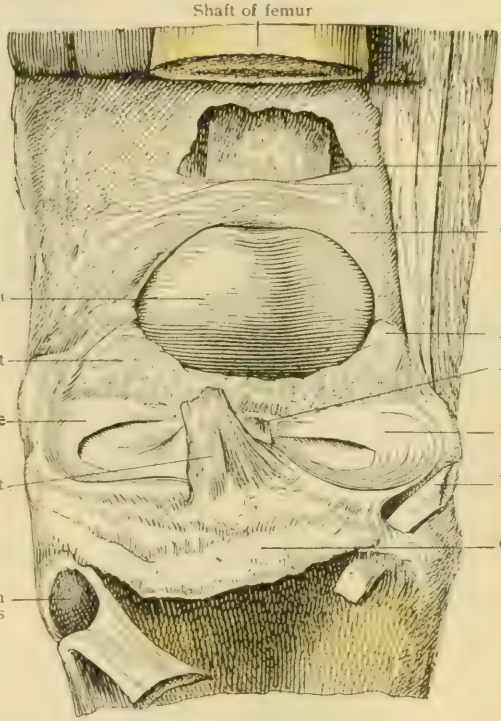
[2] For various statistics, consult Higgins: Journal of Anatomy and Physiology, vol. xxix., 1895.

[1] Meniscus medialis.

The lower surfaces of the disks adapt themselves to the top of the tibia, the outer cartilage concealing the convexity at the back of the tuberosity. The upper surfaces form cups to receive the femoral condyles. At the sides of the spine, where the cartilages are wanting, the cups are completed by the upward slope of the tuberosities.

The **coronary ligaments** (Fig. 420) are parts of the capsule connecting the periphery of the semilunar cartilages with the tibia. They are of little strength and allow more or less motion. Those of the external cartilage are more than two centimetres long at the front and 1.3 centimetres at the back, while those of the internal are from four to five millimetres. Thus the external cartilage can move very freely on the tibia, both from the length of these ligaments and from the approximation of its horns, while the internal can move but little. This has an important influence

Fig. 419.



Anterior wall of right knee-joint seen from behind, the lower end of the femur having been removed.

on the mechanics of the joint. The popliteus muscle is attached to the outer, which is significant in the same connection.

The **transverse ligament**[1] (Fig. 420) is a band, usually ill-defined and often quite wanting, which connects the cartilages at the front of the knee, running from the convexity of the outer to near the anterior cornu of the inner and sometimes into it. It is closely attached to the capsule in front.

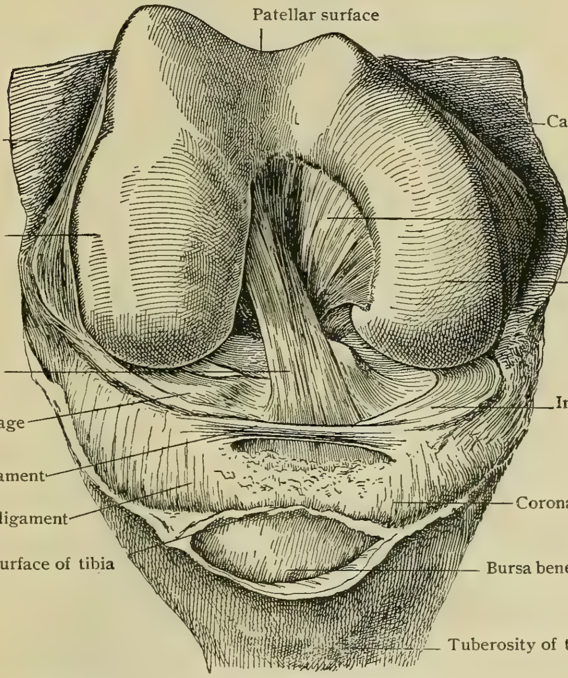
The **crucial ligaments**[2] (Figs. 419, 420) are two broad, thick bands, the strongest in the joint. The **anterior** arises from the depression in front of the spine of the tibia, close to the external semilunar cartilage, and runs upward, backward, and outward to the back of the inner side of the outer condyle. The **posterior**, the stronger, arises from the back of the groove at the posterior aspect of the top of the bone, and from its outer border, leaving the floor of the groove and the transverse piece of the spine of the tibia free and covered by synovial membrane. It is also closely connected with the external semilunar cartilage. It runs forward, upward, and a little inward to the front of the outer side of the inner condyle and of the

[1] Lig transversum genu. [2] Ligamenta cruciata genu.

intercondylar notch. The fibres from the external semilunar cartilage run along it in a varying position, but usually as a well-defined bundle. When the joint is straight the surface of the anterior ligament looks approximately forward and upward, its line of insertion being about vertical ; when it is fully flexed the outer edge is brought forward so that the ligament is somewhat twisted on itself and the upper part looks inward, the line of insertion slanting slightly downward and backward. In the former position the posterior crucial has the anterior surface looking outward, forward, and downward, the line of insertion being horizontal, with the front external. With the knee flexed the ligament is closely applied to the internal condyle.

The Subpatellar Fat, the Ligamentum Mucosum, and the Ligamenta Alaria (Figs. 419, 423).—If the joint be opened by dividing the capsule just above

FIG. 420.



Right knee-joint, opened and the knee flexed. Seen from before.

the patella, or, better, by splitting the patella and turning one-half to either side, a large **mass of fat** is seen inside the capsule, below the patella and above the front and top of the tibia, covered by the synovial membrane. This mass has a definite shape, though, of course, subject to change by pressure. It is perhaps best described as pyramidal, the base being towards the surface between the knee-pan and the tibia. When the knee is straight it fills the patellar surface of the femur and laterally passes under the condyles, filling the space between them and the tibia. It reaches to the semilunar cartilages. Towards the joint it has two free angles, a larger one below entering between the bones as just described and a smaller one above. The lateral halves, including the synovial covering, are called the **alar ligaments**[1] (Figs. 419, 423). From the middle of this mass below the patella runs a collection of fat with areolar and elastic tissue, invested by synovial membrane, to the top of the intercondylar notch. This is the **ligamentum mucosum**,[2] of little strength and not absolute constancy, which acts as a guy, preventing the mass of fat from falling away from the femur. There are also collections of fat about the crucial ligaments and at the back of the joint between the posterior crucial and the capsule.

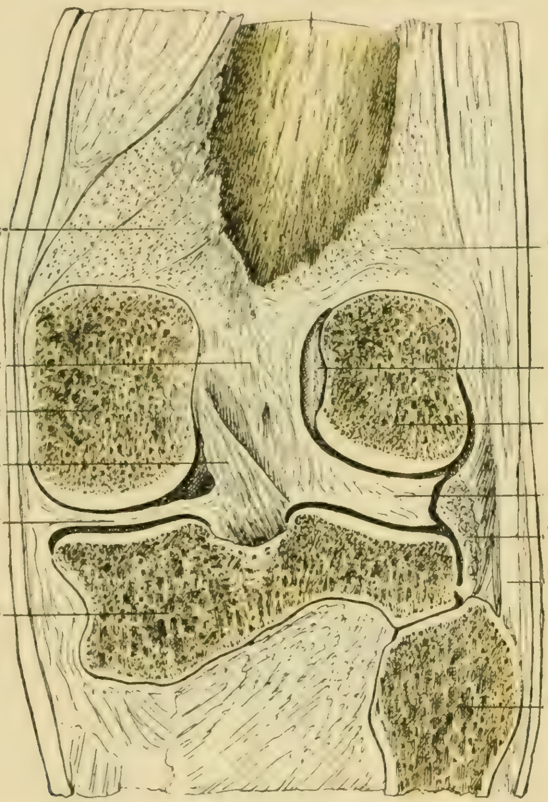
The **synovial membrane** lines the capsule in a general way, but is separated

[1] **Plicae alares.** [2] **Plica synovialis patellae.**

from it by the masses of fat just described. It surrounds the lower halves of the crucial ligaments with the fat in a common envelope, so that there is in nature no interval between them. There is but a small chink between the upper halves, though each has its separate sheath. The back of the posterior crucial is partly uncovered by synovial membrane. **Synovial fringes** formed by the membrane and more or less underlying tissue project from the folds of the alar ligaments, from the ligamentum mucosum, and from near the borders of the patella.

Bursæ.—(1) The most important is a large one under the extensor tendons, just above the capsule, with which it usually communicates. It probably in most cases develops independently of the capsule, which then lies in front of its lowest

FIG. 421.



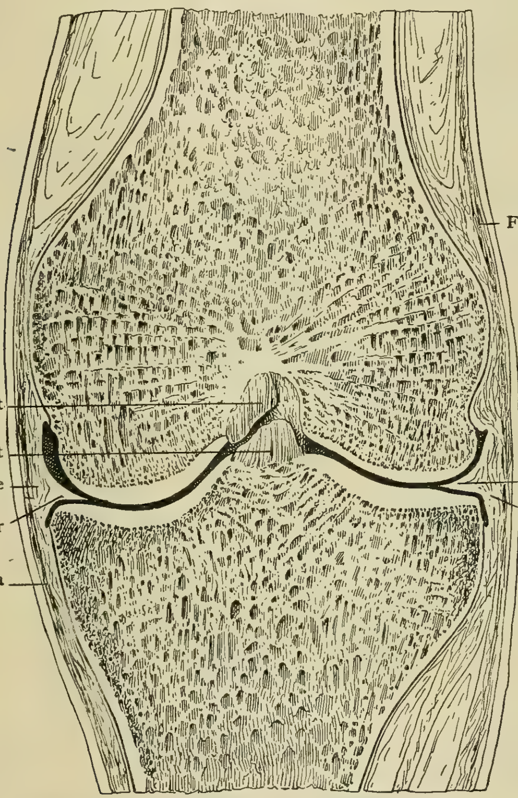
Frontal frozen section of right knee-joint passing through condyles and behind shaft of femur. Seen from behind. The superior tibio-fibular joint is opened.

part, a communication forming subsequently. Such a communication almost always exists in the adult, less frequently in the infant. The opening may be small and well defined or so large that the cavities of the joint and bursa give no sign of subdivision. This carries the cavity of the joint any part of three finger-breadths above the knee-pan. It is possible that sometimes there is a communication from the beginning. (2) *Prepatellar bursæ* are found on the front of the patella at different depths. Directly below the skin is the superficial fascia, often lamellated and adherent to the layer beneath it. According to Bize,[1] *(a)* a bursa is present in this superficial layer, usually over the lower half of the patella, in eighty-eight per cent. of knees examined. The next layer is an aponeurotic one continuous with the fascia lata, beneath which *(b)* a bursa is found in ninety-five per cent., most commonly at the inner inferior part. A still deeper *(c)* bursa occurs beneath

[1] Journal de l'Anat. et de la Phys., 1896.

the fibrous layers from the tendon of the quadriceps over the lower part of the bone in eighty per cent. (3) A large and constant bursa lies on the smooth anterior surface of the tubercle of the tibia beneath the ligamentum patellæ, which is inserted into the lower part. It extends upward to about the level of the top of the tibia, from which it is separated by the fat below the knee. It practically never communicates with the knee-joint. As the tendon before it is inserted obliquely, descending lower on the outer side, the shape of the bursa is roughly triangular. The greatest diameter is the transverse one at the top, the outer border is not quite so long, and the inner about half the length of the outer. The breadth is from 3 to 4 centimetres, the outer border from 2.5 to 4, and the inner from 1.5 to 2.5 centimetres. (4) A subcutaneous bursa is often found over the tuberosity of the tibia

FIG. 422.



Frontal section through middle of right knee-joint. Seen from behind.

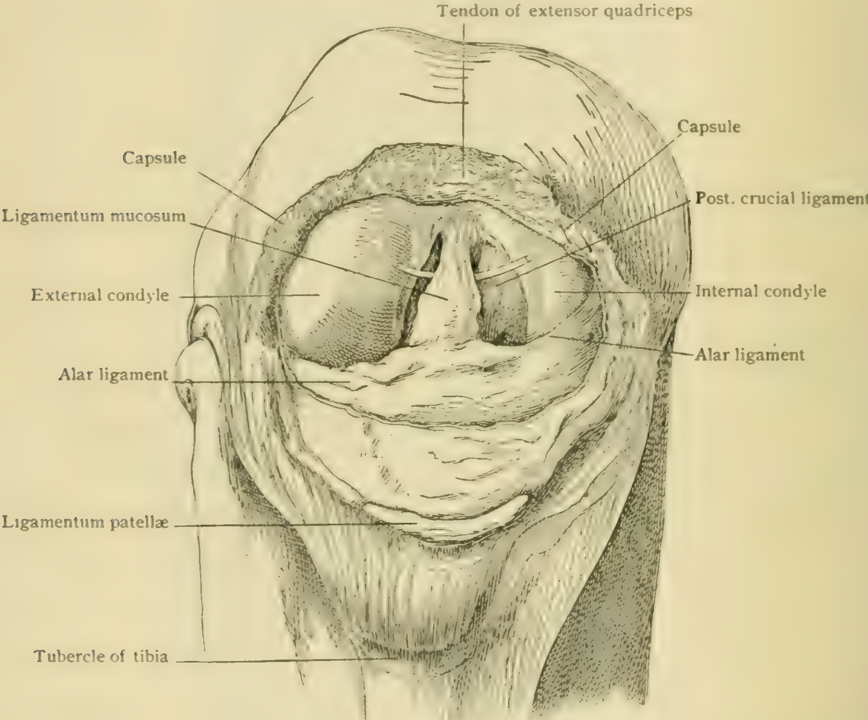
and (5) another over the ligament of the patella. At the back of the knee there are several bursæ. (6) The largest is that beneath the inner head of the gastrocnemius (Fig. 426), which later in life often connects with the joint. It is usually prolonged between the gastrocnemius and the tendon of the semimembranosus. (7) A bursa is commonly found between the long lateral ligament and the tendon of the popliteus as it passes beneath it, and another between the ligament and the tendon of the biceps.

The *relations of the tendon of the popliteus muscle* are so important as to require a separate description. The muscular belly is usually separated from the back of the tibia, near the top, by a prolongation of the capsule between the tibia and the back of the external semilunar cartilage, which is described by some as a bursa communicating with the joint. According to either view, there is a deficiency of the coronary ligament at this point. The muscle is connected beyond this with the outer side of the external semilunar cartilage. Passing above this, it becomes a part

of the capsule, and on reaching its insertion it makes a more or less prominent projection into the joint. There may or may not be a projection of the capsule like a bursa at the point where the two are fused. On its way the tendon often sends some fibres to the posterior crucial ligament.

Movements.—The motions between the femur and the patella will be considered after those between the thigh and the leg. The knee cannot be a hinge-joint, for in such the moving part is always at the same distance from the axis of rotation, which is out of the question in the knee, owing to the shape of the condyles. The fact that these are neither of equal length nor parallel complicates the problem. The joints are further subdivided by the semilunar cartilages, which make a slight socket for each condyle. This socket is more or less movable and also compressible and elastic, so that it may change its shape to accommodate itself to the form of

Fig. 423.



Patella removed from right knee, which is strongly flexed to show alar ligaments and ligamentum mucosum. A probe is passed beneath the latter.

different parts of the condyle. The external semilunar cartilage, having its horns securely attached near together and having a long coronary ligament, can swing backward and forward pretty freely as a whole. The internal cartilage is more closely fastened to the tibia, excepting the anterior horn, which has no constant arrangement. Not only can the semilunar cartilages change shape, but, as Braune has shown, the cartilage of the joint is capable of compression. For all these reasons accurate mathematical statements are impossible.

In *extension* of the leg on the thigh, beginning with the knee flexed, the tibia travels along the irregular curve of the condyles, carrying the semilunar cartilages with it. There is practically no movement between the internal cartilage and the tibia, unless at the end, and probably little beneath the external. The external tuberosity of the tibia reaches the front of the shorter condyle before the internal tuberosity has completed its course. The last part of the advance of the latter is accompanied by an outward rotation of the tibia on a vertical axis passing through about the middle of the outer condyle, so that while the inner tuberosity still swings

forward, the outer part of the external swings back. This motion occurs below the external semilunar cartilage. *Flexion* begins with a corresponding inverse rotation of the tibia. While the knee is straight the tibia is firmly fixed, so that in rotation of the limb at the hip the bones move as one. The long lateral ligament and that part of the capsule called the internal ligament are placed so far back that they are relaxed in flexion but become tense in extension. Both the crucial ligaments are always nearly tense, especially the posterior. The anterior is quite tense in extension, the posterior in flexion. The latter prevents forward displacement of the femur on the tibia when, as in alighting from a leap, the whole weight is carried forward by the impetus, the knee being flexed. Another rotation on a vertical axis through the middle of the joint may occur when the knee is flexed. The motion is between the femur and the internal semilunar cartilage, and both above and below the external one. This motion is chiefly passive,—*i.e.*, imparted by another person twisting the leg when the muscles are relaxed. It probably, however, can be executed actively to some extent. It is very slight in less than semiflexion of the knee, and diminishes as flexion becomes more extreme. The precise angle at which it is greatest seems uncertain. *Rotation* of the tibia *outward*, tending to untwist the crucial ligaments, is resisted by neither, but by the internal lateral ligament. *Rotation inward* is resisted by both crucials, especially the anterior, and by the external lateral. The posterior ligament is made tense in life in positions in which it would otherwise be lax by the action of the semimembranosus. It is tense in extension. The front part of the capsule is tense in flexion and relaxed in extension, but its condition in the latter state is considerably modified by the degree of contraction of the quadriceps extensor.

Movements of the Patella.—The patella in the upright position, when the muscles are relaxed, has the lower part of the articular surface resting against the top of that of the femur. When the muscle is contracted the former is drawn entirely above the latter. As flexion begins the lower zone of the articular surface fits into the groove on the femur, the two upper and the internal strip not being in contact with it. In semiflexion the knee-pan has passed below the patellar surface of the femur, and the middle zone rests on the front of the outer condyle and on a small part of the inner. As flexion becomes extreme the patella follows the outer condyle, resting on its under side by its superior zone, the convex portion is in the notch, and only the strip along the inner edge is in contact with the outer side of the internal condyle. In the latter part of the movement the mucous ligament becomes tense, and through it, and still more by atmospheric pressure, the alar ligaments are brought close in to fill the chink between the femur and the tibia.

PRACTICAL CONSIDERATIONS.

The Knee-Joint.—The anatomical conditions which should render the knee-joint peculiarly subject to dislocation are as follows: 1. Its situation between the longest bones of the skeleton and its consequent exposure to tremendous leverage. 2. Its similar exposure to frequent strain and traumatism. 3. The extensive and varied character of its movements. 4. The absence of bony prominences, which could effectively strengthen the joint, upon either the articular surface of the lower end of the femur or the shallow upper surface of the tibial tuberosities.

The ability of the joint to resist dislocation, which is of very rare occurrence, lies in (*a*) the strength of the ligaments, especially the crucial; (*b*) the expansions of the quadriceps tendon on the front of the joint; (*c*) the reinforcement of the posterior ligament by the semimembranosus tendon; (*d*) the similar relation of the internal lateral ligament to the semimembranosus, and of the external lateral to the tendons of the biceps and popliteus; (*e*) the power thus conferred upon strong muscles to meet and modify or resist sudden strains by varying the tension of the capsule and even of the ligaments; (*f*) the deepening of the tibial cup by the semilunar cartilages, and the adaptation of the latter to the varying positions of the bones so that the contact between and pressure upon the joint-surfaces are as extensive and as uniform as the shape of the condyles will permit.

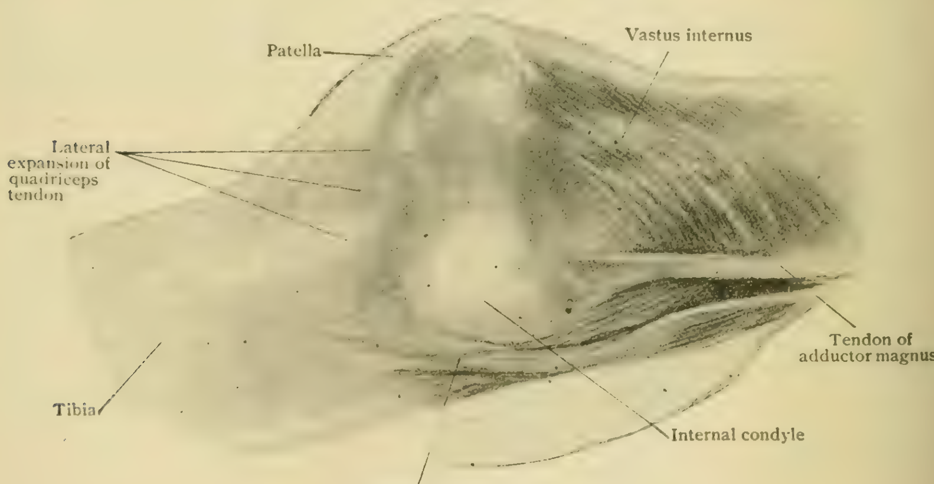
Dislocations of the knee may be antero-posterior or lateral in direction. The

former usually and the latter invariably are incomplete, owing to the large superficial areas of the joint-surfaces. In the great majority of cases dislocations of the knee are due to indirect violence acting through the femur as a lever,—as, for example, in falls forward, the foot and leg being fixed. The weight of the trunk carrying the upper end of the thigh forward, brings the lower end with great power—the fulcrum and the resistance, or weight, being so close to each other—against the posterior ligament, a rupture of which permits the movement to continue and results in an anterior dislocation of the knee, which is, regarded from an etiological stand point, a displacement of the femur backward.

If the fall is in the opposite direction, the femur may be displaced anteriorly,—*i.e.*, posterior dislocation of the knee may occur. Occasionally the anterior dislocation has followed the fall of a weight upon the front of the femur. The application of force to the front of the leg when the knee was flexed has produced a posterior dislocation, the effect of the biceps, popliteus, and semimembranosus in reinforcing the posterior ligament being minimized in that position.

Lateral dislocations are caused by adduction or abduction of the leg, the thigh being fixed, or by falls sideways when the foot and leg are fixed. The great width

FIG. 424.



Inner aspect of right knee-joint, showing expansion of quadriceps tendon.

of the joint and the slight resistance offered by the interposition of the tibial spine between the femoral condyles render them rarer than antero-posterior luxations.

Forward dislocation is more common, possibly because of the greater laxity of the capsule in front, and is more apt to be complete than the backward. The knee is extended; the tibial tubercle prominent; the antero-posterior diameter increased; the anterior margin of the tibial tuberosities palpable in front; the rounded condyles may be felt, but less distinctly posteriorly; the popliteal concavity is obliterated; the aponeurotic expansion of the quadriceps is loose and lies in folds about the upper border of the patella. The femoral vessels and nerves may be bruised, compressed, or lacerated.

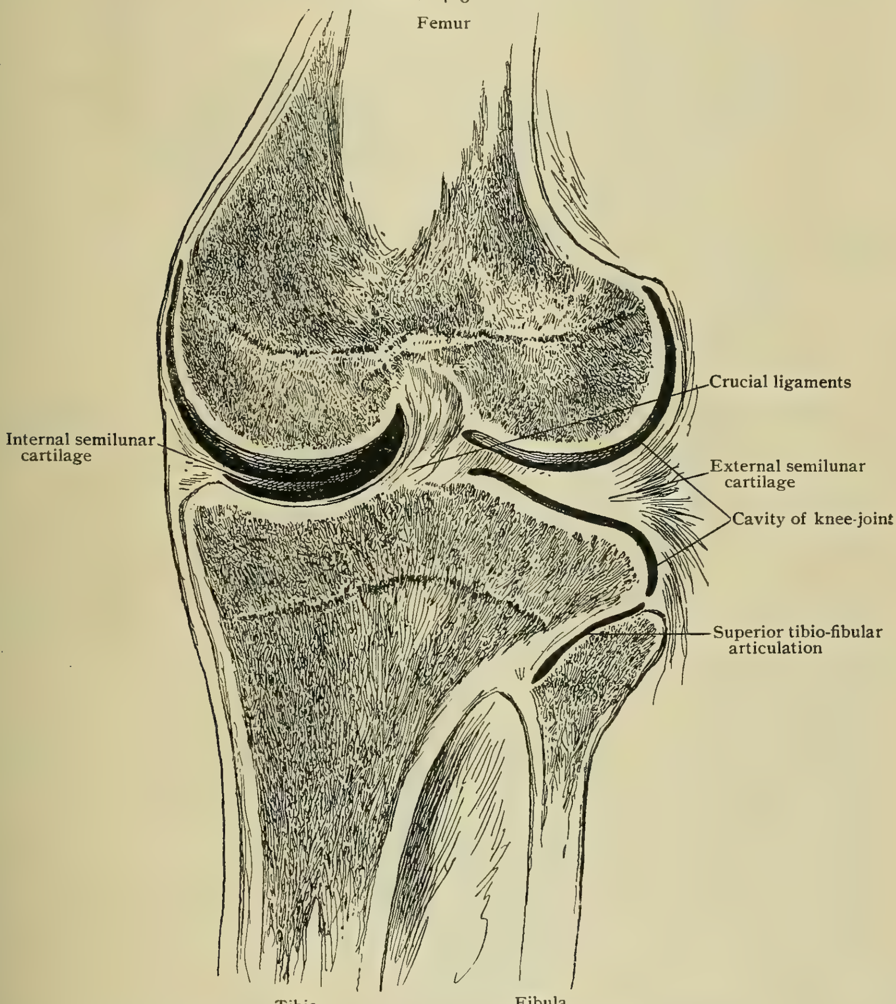
In *backward* dislocation also the knee is in extension and the antero-posterior diameter increased. The displaced bony prominences may be recognized by palpation. This dislocation is even less apt to be complete than the forward variety; but if it is, the vessels and nerves are oftener injured, as shown by the more frequent occurrence of gangrene. This is probably due to the sharpness and prominence of the backward projection of the upper edge of the tibial tuberosities, as compared with the rounded depressed notch between the femoral condyles which receives the vessels in forward dislocation.

In *lateral* dislocation, in accordance with the direction of the displacement,

one or other condyle becomes prominent, as does, on the opposite aspect of the limb, the head of the fibula or the inner tuberosity of the tibia. The patella, owing to the shortness and strength of its ligament, is carried with the tibia. The lateral diameter of the joint is increased. The foot is apt to be rotated in the direction of the luxation owing to the tension of the biceps in the outward and of the popliteus and inner hamstrings in the inward variety.

Dislocations by *rotation* have also occurred.

FIG. 425.



Frontal section through knee-joint, showing articulating surfaces and epiphyseal lines.

In the various forms of luxation the crucial, the lateral, and the posterior ligaments and the biceps and gastrocnemius muscles suffer most severely; the popliteus and semimembranosus less so. They are often compound, and may for that reason necessitate amputation. The injury to the ligaments leaves the joint weak and insecure for a long time.

Subluxation of the semilunar cartilages occurs usually when the leg is fixed, the knee slightly flexed, and the femur rotated upon the tibia, because the movements of flexion and extension take place between the femur and these cartilages, which, therefore, follow the motion of the tibia; whereas in rotation—the move-

ments then occurring between the tibia and the cartilages—one of them is fixed between the corresponding condyle and the tibia which rotates beneath it; the remaining cartilage, especially if the rotation is marked, may be dragged or squeezed so that it is nipped between the tibia and femur. Thus the contraction of the biceps which effects outward rotation of the leg brings more closely together the external tuberosity of the tibia and the external condyle, and the outer cartilage is held firmly between them. This increases slightly the distance between the internal condyle and the head of the tibia, leaving the internal cartilage freer to move into an abnormal position. When the popliteus, semitendinosus, and semimembranosus contract to rotate the leg inward, they, in like manner, fix the internal cartilage and allow of increased mobility of the external cartilage.

Subluxation of the inner cartilage is the more frequent because (1) outward rotation of the leg is far more common than inward rotation; (2) the muscle chiefly concerned in effecting inward rotation,—the popliteus,—when it contracts, steadies and supports the external cartilage by pressure against its outer margin (Morris); no corresponding support is given the internal cartilage during outward rotation; (3) the anterior crucial ligament is attached somewhat in front of, and often directly to the inner cornu of the external cartilage, tending to limit its forward motion. It is altogether behind the internal cartilage; (4) the external cartilage has a strong attachment to the femur through the ligament of Wrisberg posteriorly.

The displacement is forward in the majority of cases. The symptoms are pain, from the pressure on the cartilage itself, increased by reflex spasm of the muscles moving the joint, and followed by a synovitis. The edge of the cartilage may often be felt.

Disease of the knee-joint is of great frequency on account of its exposure to (*a*) direct violence and to cold and wet, by reason of its superficial position, and (*b*) to strains and wrenches through the leverage of the femur and tibia. The factors competent to resist luxation are not able to protect it from minor injuries. It is a favorite seat, therefore, of traumatic synovitis, and—on account also of its complexity, its large size, and the difficulty in keeping it at absolute rest—disease, if acute, is apt to be severe and threatening; if subacute, tends to become chronic or to recur. All the above reasons, combined with its inclusion of the lower femoral epiphysis and its close relation to the upper tibial epiphysis,—the seats of the chief growth of the lower limb,—make it also one of the joints most commonly subject to tuberculous disease, while gout, rheumatism, and syphilitic and gonococcic infection are often localized in it.

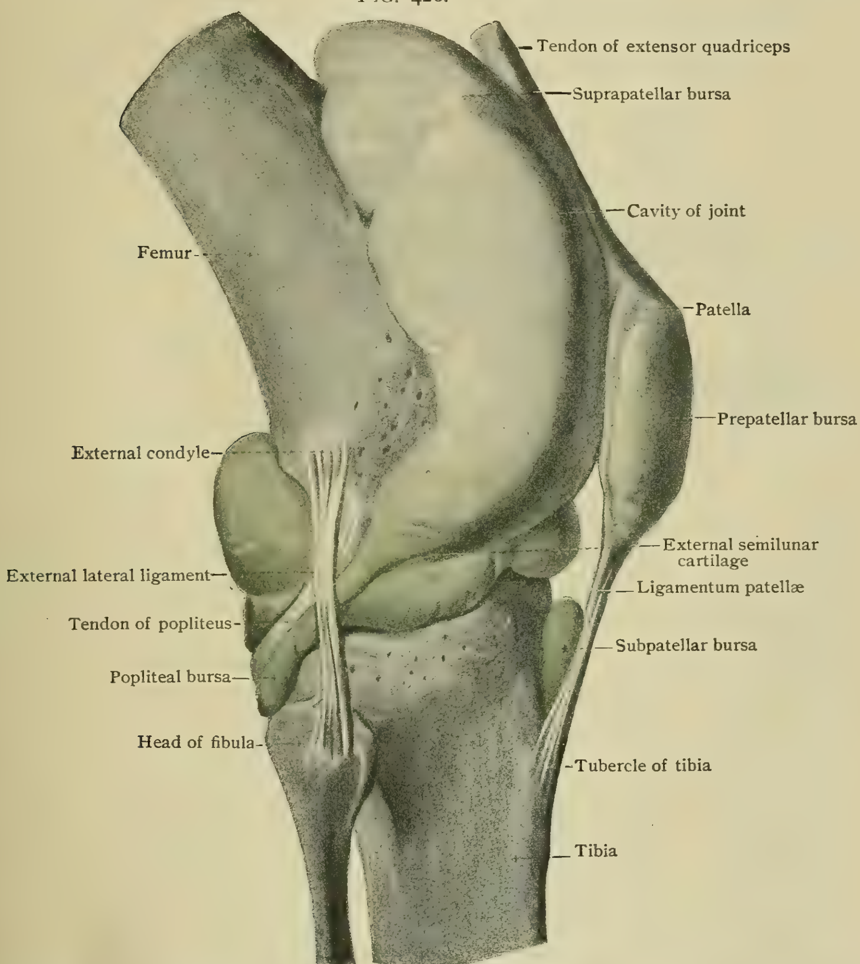
Most of the chronic diseases due to infection, as well as those directly following traumatism, begin in the synovial membrane because of the large superficial expanse of that membrane. The intra-articular effusion—whether "simple," from hyperæmia, or inflammatory, from infection—causes the knee to assume the position of moderate flexion because (1) its capacity is then greater than in full extension or full flexion, and maximum capacity is equivalent to minimum pressure; (2) flexion relaxes the densest and most resistant ligaments,—the posterior and the lateral (as they are attached behind the centre of the bone) and (if moderate) the posterior crucial. It is resisted only by the ligamentum patellæ, which is in less close relation to the joint (being separated by the pad of fat on which it lies), and by the thinner and more extensible anterior portion of the capsule; (3) the joint is innervated in accordance with the general law that the same nerves which supply the interior of an articulation supply also both the muscles moving it and the skin over the insertion of those muscles (Hilton). The knee-joint is acted on by ten muscles, four of which are extensors and six flexors. The latter are not only numerically in excess, but are also the more powerful and the more favorably situated for acting upon the joint. Therefore, when the articular twigs of the obturator, sciatic, and anterior crural nerves are irritated by disease, and both the anterior and posterior groups of muscles contract reflexly, the flexors predominate. The principle is of wide-spread application, and should be considered in reference to the position of most joints, at least in the early stages of disease.

Later in knee-joint disease the softening and elongation of the ligaments permit the pull of the flexors to produce posterior displacement of the bones of the leg

upon the thigh. This is aided in dorsal decubitus by gravitation, which also favors the outward rotation of the leg that commonly occurs at the same time.

The swelling of synovitis, whether acute or chronic, is limited, until the capsule gives way, by the attachments of the synovial membrane,—that is, it extends upward beneath the rectus for from two to three finger-breadths or from four to five centimetres (one and a half to two inches) above the summit of the patella; laterally, it reaches the same level under the vastus internus, but is not quite so high on the other side, under the vastus externus. Downward, it descends to nearly the middle of the ligamentum patellæ, attaining the same level on the inner side, but stopping

FIG. 426.



Right knee-joint. The joint-cavity and several bursæ have been distended with injection mass before dissection. (*Spalteholz.*)

just above the head of the fibula on the outer side. The patella is separated from the trochlea of the femur—"floated up." In testing for this symptom, it is important to grasp the anterior muscles of the thigh firmly and draw them towards the knee so as to relax the pull of the quadriceps, which is occasionally great enough to hold the patella in contact with the femur, even in the presence of considerable effusion (Fig. 426).

The condition is usually unmistakable, but may have to be differentiated from periarticular abscess or hæmatoma. In the latter cases the swelling will not be uniform; the inner depression at the side of the patella may be obliterated, and not

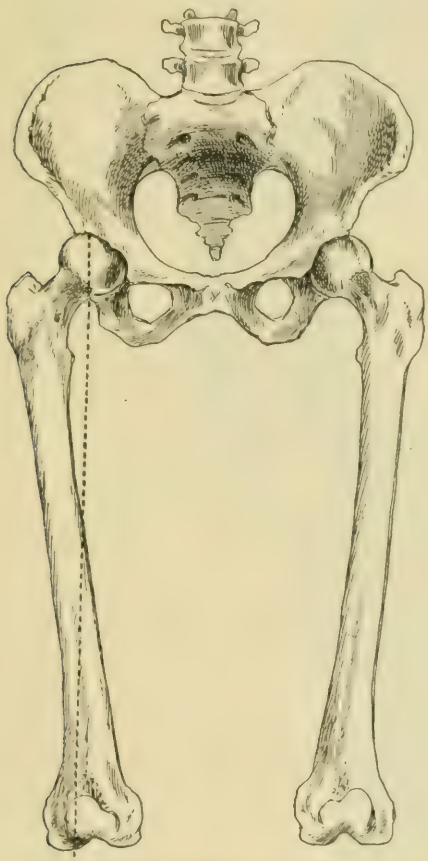
the outer, or *vice versa ;* fluctuation cannot be obtained in every direction,—*i.e.*, from side to side under the patella or obliquely ; the patella will lie directly upon the femur.

The diagnosis from bursal enlargements will be considered in relation to those structures.

Syphilitic disease of the gummatous type is apt to begin in the subcutaneous tissue without the joint, which it involves secondarily. In its earlier stages the swelling would therefore be periarticular, and recognizable by the foregoing symptoms. Later, as it extends in both directions, there will usually be ulceration of the skin.

The knee is more often the seat of the so-called *loose bodies* than is any other joint. They are sometimes the result of osteo-arthritis (which affects the knee by preference), causing thickening and fibrinous or calcareous change in some of the synovial fringes ; or they may be produced in those fringes from embryonic remnants, and are then composed of hyaline cartilage or fibro-cartilage ; or they may result from the organization of inflammatory lymph after an acute arthritis ; or they may be portions of an interarticular or articular cartilage detached by violence, although this is rare.

Fig. 427.



Line of pressure between hip and knee.

In a case of suppurative arthritis the incisions for *drainage* should be made on either side of the patella and a little below its middle, and should be placed towards the posterior aspect of the lateral pouches of the synovial membrane.

Genu valgum — "knock-knee" — in young children may be directly due to rickets, or may follow Charcot's disease, infantile paralysis, or any sprain or dislocation of the knee that leaves the internal lateral ligament weak or defective. In children and adolescents without these antecedents its essential cause is still a matter of dispute. There can be no doubt, however, that in the great majority of cases the production of the deformity is favored by static modifications of certain anatomical conditions which are probably the cause and not the result of the diaphyseal overgrowth of femur and tibia (Mikulicz), of the contraction of the biceps and tensor vaginæ femoris (Duchenne), of the elongation of the internal lateral ligament (Stromeyer), and of the atrophy of the external condyle (Ollier) which are found in most cases of this deformity, and each of which has been given etiological importance.

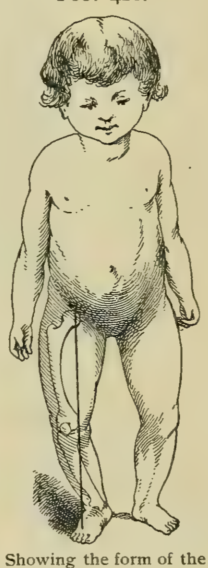
The angle between the femoral and tibial axes (corresponding to that between the arm and forearm) opens outward at the knee. It results not, as in the upper extremity, from an outward obliquity of the lower segment of the limb, but from the inward slant of the thighs from the pelvis to the knees, the tibiæ (like the humerus) being parallel to the longitudinal axis of the body and to each other. That the line of the knee-joint may be horizontal, the internal condyle of the femur is longer than the external. In a normal person standing erect in the military attitude of "attention" the weight of the trunk is transmitted downward from the head of the femur in a vertical line which passes through the external condyle (Fig. 427). The erect position must therefore be maintained, not merely through the approximation of the

bones, as would be the case if the axis of the whole lower limb were a perpendicular running through the acetabulum and the centre of the ankle-joint, but by the help of muscular and ligamentous structures.

The tendency (which is so common a factor in the production of deformities) to assume an attitude which will transfer strain from a tired muscle to the neighboring ligaments operates here to cause stretching and elongation of the internal lateral ligament, as the "attitude of rest" with the feet separated and everted is the one usually adopted. The evil effects are, of course, favored by much standing, and are most marked in young persons of feeble physique whose weight has increased disproportionately to their muscular strength. The outer side of the knee shows the changes due to increased pressure and to long-continued approximation of musculo-tendinous points of origin and insertion,—*i.e.*, atrophy of the outer condyle and outer tuberosity; contraction and shortening of the ilio-tibial band of fascia, of the external lateral ligament, of the tendon of the biceps, and of the tensor vaginæ femoris. The inner side shows the effects of removal of normal pressure from growing bones and of chronic strain of fibrous and periosteal tissue,—*i.e.*, overgrowth of the femoral diaphysis just above the inner end of the epiphyseal line and of the tibial diaphysis just below the corresponding level; lengthening of the internal lateral ligament; bony outgrowth at its tibial insertion from chronic periostitis.

The tibia is apt to be rotated outward, possibly through the action of the shortened biceps. Talipes valgus (*q.v.*) may be either a cause or a result of genu valgum. The disappearance of the deformity when the knees are flexed is probably due to the outward rotation of the femur that accompanies flexion, and not, as is generally stated, to the fact that the antero-posterior diameter of the condyles is unaffected by the disease.

FIG. 428.



Showing the form of the bones in bow-legs.

The clinical symptoms and results and the treatment by apparatus cannot be described here.

In *Macewen's osteotomy* the femur is divided from the inner side of the thigh at a point twelve millimetres (half an inch) above the adductor tubercle and in a line at right angles to the long axis of the femur. Osteotomy may also be done from the outside of the thigh and at the same level. These operations are usually safe, but the popliteal artery, the anastomotica magna, the external peroneal nerve, and other important structures have been accidentally divided.

Genu varum—"bow-leg"—is almost always rhachitic in its origin. A child with rickets and having lumbar lordosis of the spine stands with its thighs slightly flexed, either as a secondary result of the shortening of the ilio-femoral ligaments produced by backward rotation of the pelvis (to compensate for the forward rotation of the sacrum) or more simply as an easy method of relaxing the weak ilio-psoas muscles and preserving the centre of gravity. As the thighs flex the knees separate, the femurs rotate outward on their own axes, the line of gravity falls to the inside of the centre of the knee-joint (Fig. 428), the pressure is greatest on the inner condyle and tuberosity, the strain comes upon the external lateral ligament, and the outward bowing begins and is continued by the leverage of the body weight.

Genu recurvatum—"back-knee"—is a deformity in which, as a result of intra-uterine malposition, or of congenital paralysis of the flexors and popliteus, or of pressure brought upon the posterior and crucial ligaments in walking in a case of partial paralysis of the quadriceps,—the limb being swung forward, the heel coming to the ground in full extension, and the weight of the body reaching the joint in front of its centre of gravity,—the knee is bent backward and the whole limb presents a long curve with its concavity forward.

In *excision* of the knee the lines of the epiphysis should be remembered if the patient is under twenty or twenty-one years of age (page 365), the relation of the femoral vessels to the posterior ligament, the situation and extent of the synovial

pouches (which in infectious cases are usually involved), the direction of the articular line (with which the saw cut should be parallel), and sometimes the possibility of infection of the neighboring bursæ.

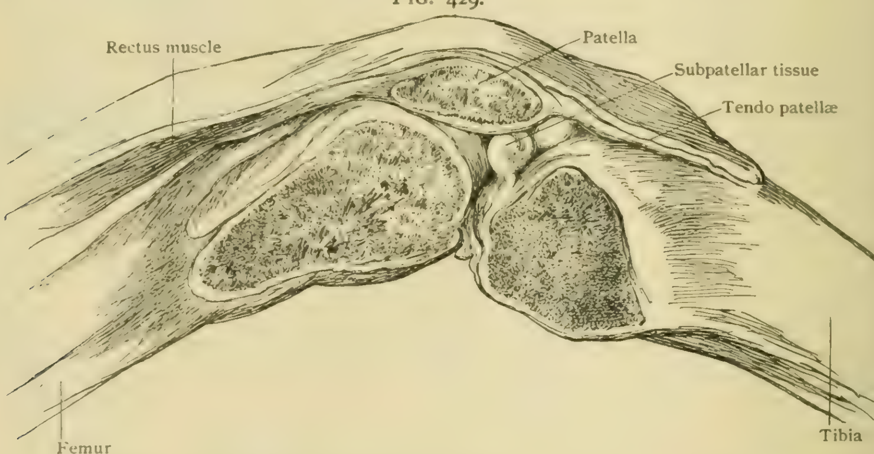
Landmarks.—The synovial membrane rises from four to five centimetres (one and a half to two inches) above the upper border of the patella; it is higher on the inner than on the outer side of the thigh; its upper limit descends in flexion of the knee.

The bony points have been described in connection with the femur and tibia (pages 367, 390); the bursæ will be described later.

The Patella.—*Congenital absence* of the patella on one or both sides has been noted in a number of instances, and has in some cases been observed in several members of the same family. The functional disability was slight or altogether unnoticeable.

Fracture by muscular action is more common in this bone than in any bone of the skeleton. It occurs usually with the leg in partial flexion upon the knee. In this position fracture is favored because (1) the ligamentum patellæ is then taut and fixes the lower edge of the bone; (2) the patella is in contact only through the upper third of its convex under surface with the most prominent part of the articular surface of the condyles (Fig. 429); and (3) at this time the quadriceps extensor

FIG. 429.



Showing position of patella in relation to condyles of femur with knee partially flexed.

has the greatest advantage of leverage upon the patella, as when the knee is fully bent the muscle gets its leverage for the beginning of extension through the projection of the front of the condyles, and the patella lies on the pad of fat between the femur and tibia (Fig. 430), and when the knee is almost or quite extended, the patella—or three-fourths of it—occupies the depression of the trochlea, or even that just above it. As a result of the cross-strain brought to bear in the partially flexed position the bone usually breaks transversely a little below its mid-line,—*i.e.*, through the area unsupported by the femur beneath (Fig. 429). Occasionally it gives way at a higher level.

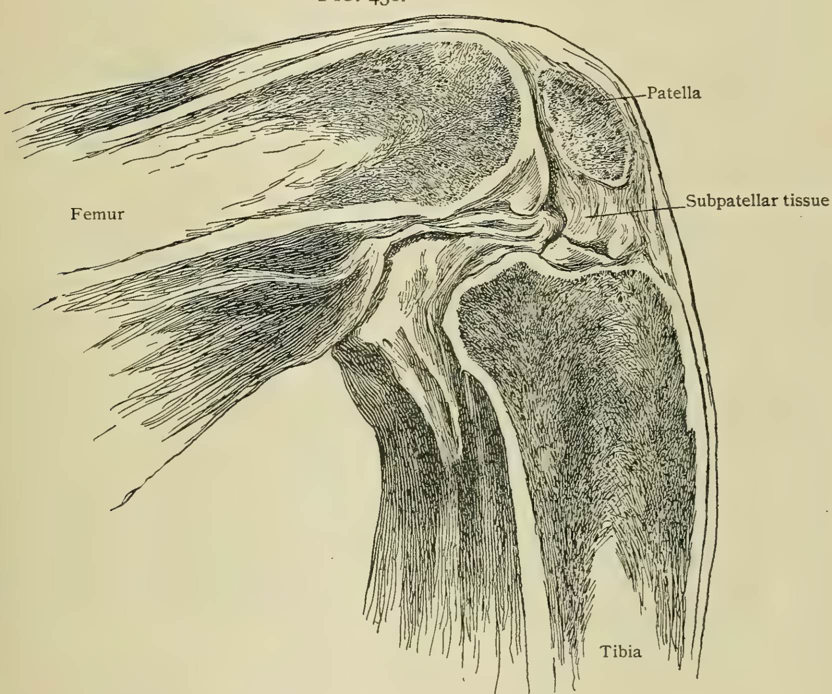
The accident may happen as the result of a fall, but the fall is more apt to follow than to precede the fracture. In ordinary falls upon the knee the force is received upon the tubercle of the tibia, not upon the patella.

Direct violence often causes an irregular, comminuted, or stellate fracture.

Fracture never occurs in children and is extremely rare before adult life. When the bone is broken the fragments are immediately separated by the action of the quadriceps upon the upper one. The degree of their separation will depend upon the amount of laceration of the lateral aponeurotic expansions of the conjoined tendon. Unless that fibrous structure is torn, no great separation of the fragments can occur, as it is inserted into the borders and front of the patella.

which is thus embedded, as it were, in a hood spread out over the front of the joint and extending to the lateral ligaments and to the oblique lines running up from the tubercle to the tuberosities (Fig. 424). The force causing the fracture in cases of direct violence, or atmospheric pressure on the front of the knee if the fracture was from muscular action, drives in between the fragments, as they separate, in the shape of shreds or of an irregular fringe, portions of that part of the rectus tendon which was inserted into the longitudinal grooves or striæ on the anterior surface of the bone. These offer an obstacle to bony union. As the synovial membrane of the knee-joint lies in contact with, and is attached to, the under surface of the patella, it will usually be lacerated,—*i.e.*, the knee-joint will be opened and the fragments surrounded by bloody synovial fluid. The synovial membrane is reflected from the patella some distance above the apex of the bone; hence a fracture may occur at that level without involvement of the joint. The pad of fat on which

FIG. 430.



Showing position of patella in relation to condyles of femur with knee flexed at right angle.

the tip of the bone rests, and over which the membrane is reflected, may aid in saving the joint from injury.

The common failure to get bony union by non-operative methods is thus seen to be due to (1) separation of the fragments by the quadriceps, (2) the interposition of portions of the capsule, (3) the presence of blood-clot and synovial fluid, and is supposed to be further favored by (4) the sesamoid character of the bone inclining it to unite by fibrous rather than by bony tissue. It has been asserted, however (Wirth), that the patella is a detached portion of the upper tibial epiphysis and not a true sesamoid bone.

As non-union is common on account of the above anatomical conditions, operative measures are often resorted to. In the open operations used in old united fractures the fragments are drilled obliquely from a half-inch above and below the line of fracture to just above the cartilaginous under surface, so that the wire used to hold them together does not lie in the joint.

To approximate the fragments elevation of the limb sometimes suffices, but occasionally partial section of the lateral expansions of the quadriceps, of the rectus tendon, and of the muscle itself will be required as successive steps.

In the best of the operations used in recent fractures, and which do not widely open the joint, a silk or silver ligature is carried through an incision at the lower border of the patella behind that bone and between it and the trochlear groove in the femur, is brought out through an incision at the upper border, rethreaded on a needle with an eye near the point, brought down in front of the patella,—beneath the skin,—and tied or twisted so as to hold the fragments together. The blood-clot and synovial exudate are squeezed out through the two incisions ; the entangled capsular fibres are removed by attrition of the fractured surfaces against each other. These operations are, of course, not applicable to old fractures in which shortening of the muscle has taken place and approximation and forcible rubbing together of the fragments are impossible.

Operations for recent fracture by open arthrotomy permit the direct removal of the fringe of interposed tendinous and capsular fibres and the repair by suture of the rents in the capsule and in the lateral expansions of the quadriceps. The patellar fragments may also be sutured, but this is not always necessary.

Dislocation of the patella usually occurs from muscular action and as a consequence of sudden contraction of the quadriceps.

The displacement is commonly in the outward direction because the long axis of the quadriceps muscle and tendon is inclined to that of the ligamentum patellæ in such a way that the bone is situated at the apex of an obtuse angle which opens outward. When the quadriceps contracts the tendency is to straighten this angle, —*i.e.*, to carry the patella outward,—and this, aided by the greater strength of the vastus externus as compared with that of the inner vastus, is more than sufficient to overcome the resistance offered by the greater prominence of the external condyle, as well as the relatively more extensive insertion of the vastus internus into the inner margin of the patella. The bone may even, as in one recorded case, be carried entirely past the condyle, so as to lie behind the centre of motion of the knee when the joint is bent, thus causing the quadriceps extensor to act as a flexor of the leg on the thigh.

The external articular facet on the under surface of the patella is larger than the internal. The patella is in relation, therefore, chiefly with the external condyle, and even if dislocation occurs from direct violence, it is more likely to be driven in that direction (Humphry). If it has once passed beyond the edge of the outer condyle —a "complete" luxation necessarily attended by laceration of the capsule—it is less likely to be replaced than if it had gone in the opposite direction, because of (*a*) the resistance offered by the prominence of the condyle itself and (*b*) the greater comparative strength of the vastus externus.

Outward luxation is not very rare in cases of genu valgum, and, per contra, in congenital cases of patella luxation and in unreduced traumatic luxations genu valgum has followed (Makins).

The patella may be displaced inward by direct force. It is sometimes turned on edge by a force insufficient to dislocate it completely, and is held in that position by the tension of the soft parts attached to it and by the pressure of the overlying fascia, "like a stick on end under a tightly stretched sheet" (Stimson). In flexion of the knee the patella lies deeply in the depression between the condyles and the quadriceps tendon is on the stretch. The bone is therefore somewhat removed from danger of direct violence, and is steadied and fixed by the quadriceps muscle. In extension the patella rests on the trochlear surface of the femur only by its lower margin ; it is more prominent and thus more exposed to force directly applied ; the quadriceps is relaxed, leaving the bone freely movable. For these reasons extension is the position in which dislocation most commonly occurs.

THE FOOT.

The framework of the foot consists of the *tarsus*, *metatarsus*, and *phalanges*, which differ in their proportionate size from the corresponding divisions of the hand. Thus, in the latter the carpal region is the shortest and that of the phalanges the longest, equalling almost precisely the other two ; in the foot, on the contrary, the region of the phalanges is the shortest and that of the tarsus makes about half the entire length. The tarsus differs also in its arrangement more than the carpus from the primitive type. The tarsal bones may be considered as divided into two lateral divisions : an *outer series* of two bones bearing the two outer toes, and an *inner series* of five bearing the three inner toes, so placed that the proximal bone of the inner part rests on top of the proximal of the outer. The outer side of the skeleton of the foot rises but little from the ground, while the inner is highly arched.

THE TARSAL BONES.

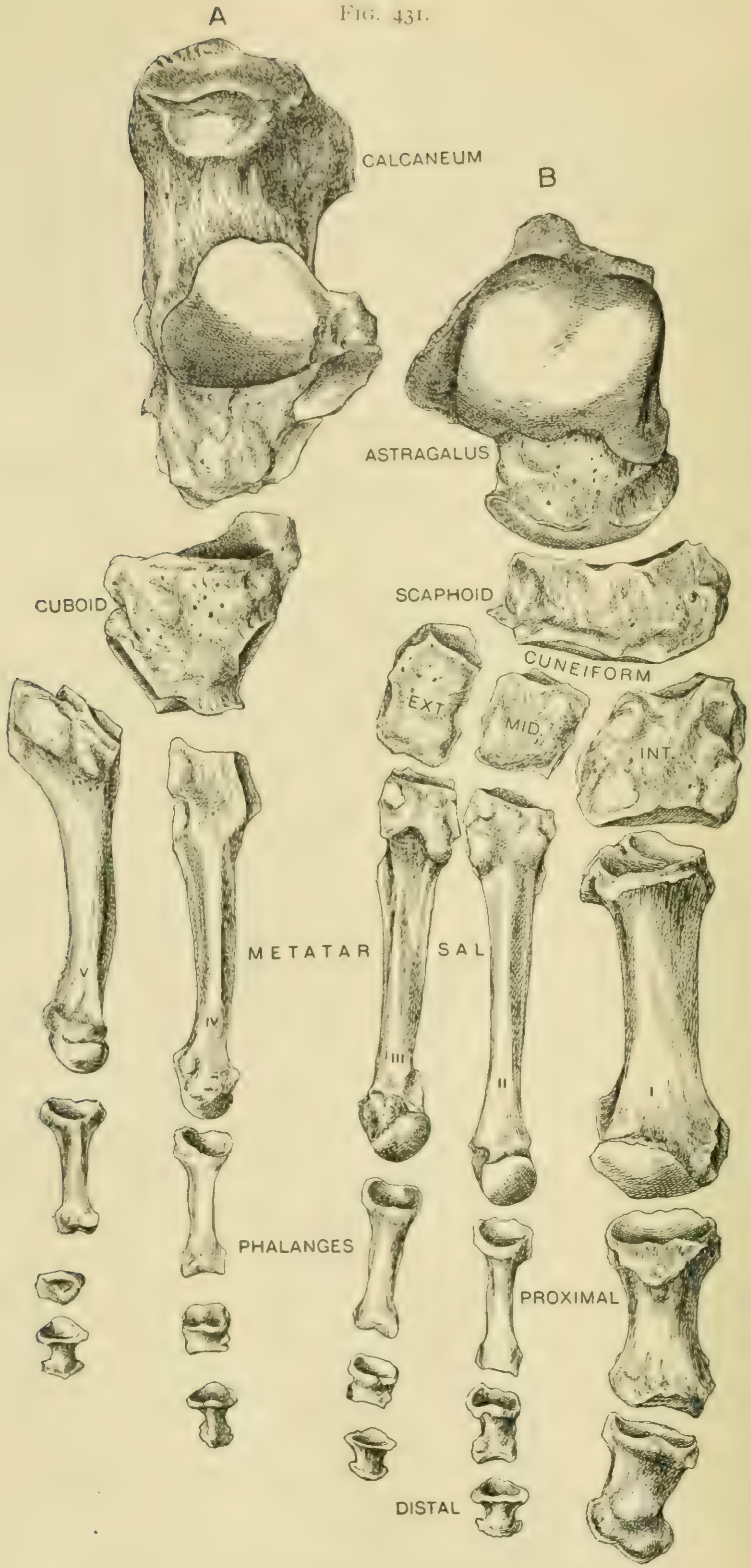
The tarsal bones are the *calcaneum*, or *os calcis*, the heel-bone ; the *cuboid*, which with it forms the outer division ; the *astragalus*, or *talus*, which joins the leg ; the *scaphoid*, placed between the *astragalus* and the three *cuneiform*, which bear the three inner *metatarsals*.

THE CALCANEUM.

The calcaneum[1] is a narrow elongated bone forming the heel, supporting the astragalus, and joining the cuboid in front. It has six surfaces. The **inferior surface** presents at the back a swelling subdivided into the *internal* and *external plantar tubercles*, of which the former is much the larger, forming the posterior pier of the foot. These tubercles are continuous at the posterior border, in front of which a deep notch divides them. Each appears on its side of the bone. In front of these the lower surface, convex from side to side, is marked by longitudinal grooves. Near the front is the *anterior tubercle*, a small swelling, from which and from a depression near it arise calcaneo-cuboid ligaments. The **posterior surface** is roughly oval with the small end up. The tendo Achillis is attached to a roughness occupying its lower half, above which the bone slants forward and is smooth for a bursa between it and the tendon. The lower part of the posterior surface is continuous with the plantar tubercles. The **internal surface** is smooth and concave ; for the internal tubercle projects strongly inward, while in front and above there is a shelf-like process, the *sustentaculum tali*, to support the head of the astragalus, slanting downward and forward. Beneath this is a slight groove for the tendon of the long flexor of the great toe. Lower down near the front border a depression for a ligament to the cuboid runs down in front of the anterior tubercle. The **external surface** is the longest. It presents about its middle a vague *tubercle* for the middle bundle of the outer lateral ligament of the ankle, and nearer the front a larger one, the *peroneal spine*. When well marked this is a ridge, covered with cartilage, slanting downward and forward, separating two grooves for the tendons of the peroneus longus and brevis. The outer posterior plantar tubercle projects somewhat on this side. Rather more than the anterior two-thirds of the **superior surface** are devoted chiefly to the joints with the astragalus ; the posterior portion is convex from side to side and concave from before backward. There are two articular facets : the *posterior facet*, the larger, a vaguely four-sided swelling, occupies the middle of this surface. Its long axis runs forward, downward, and outward. It is convex in this direction. The upper inner end is the broader, and near it the facet is very often concave at right angles to the long axis, but in the main it is about plane in that direction and may be even slightly convex. The *anterior facet*, long and narrow, concave from before backward, runs forward and outward, nearly parallel to the long axis of the former. It begins internally on the top of the sustentaculum and ends at the most anterior point of the bone. In about half the cases this surface is subdivided into two, and, as a rule, when it is not there is a

[1] Calcaneus.

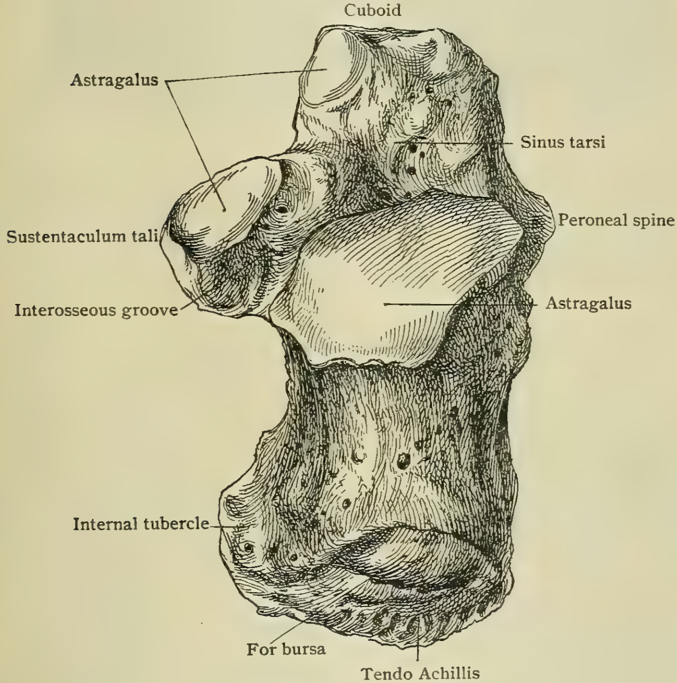
FIG. 431.



Bones of right foot, dorsal aspect. *A*, outer series; *B*, inner series.

notch in the free border just at the end of the sustentaculum. Occasionally the facet in front of the interruption is rudimentary or wanting, in which case, instead of articular cartilage, merely synovial membrane is beneath the head of the astragalus. In 200 feet we have found the facet single in 95, divided in 94, and in 11 the front was wanting. The two chief facets (counting the anterior as one, even if subdivided) are separated by a *deep groove* for the interosseous ligament to the astragalus. This gutter broadens in front into a rough depression, the *sinus tarsi*, for ligaments. At its outer part there is a tubercle for the origin of the extensor brevis digitorum. The **anterior surface**, turned somewhat inward, is wholly articular for the cuboid. It is three-sided with rounded angles. The longest diameter is from above downward and outward, nearly parallel with the inner border. The upper border is straight or convex, overhanging the joint at the inner side. The outer border slants a little inward as it descends. The surface is concave from above downward and convex transversely. Both these curves are most marked at

FIG. 432.



Right calcaneum from above.

the upper inner angle, where they form almost a groove for the plantar process of the cuboid. The general effect is of a screw surface twisting upward and inward. The calcaneum articulates with two bones, the cuboid and the astragalus, and exceptionally with the scaphoid, to which it may be united by cartilage.

Variations.—The hind end of the sustentaculum is very rarely a separate piece: *os sustentaculi proprium.* The inner edge of the front of the bone, which normally comes very near to the scaphoid, may meet it. Sometimes the two bones are fused. The *calcaneum secundarium* is a small ossicle rarely present on the dorsum between the calcaneum, the cuboid, the scaphoid, and the head of the astragalus. Fusion of the calcaneum and astragalus has been observed at the sustentaculum.

Structure.—The walls are thin, the cancellated tissue filling the bone, with a tendency to the formation of large spaces at the middle. The architectural arrangement is very clear in an antero-posterior section, which shows diverging plates from

the greater articular facet for the astragalus and a system of loops connecting them. The large spaces are at the neutral point.

FIG. 433.

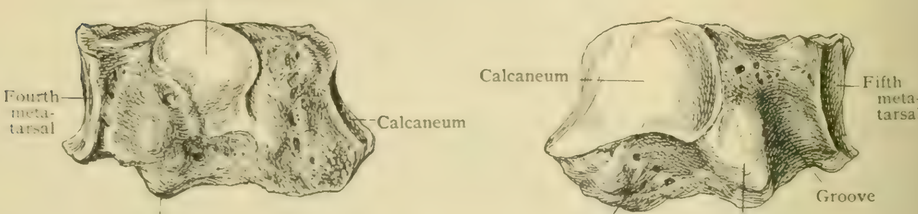
Longitudinal section of calcaneum, showing arrangement of lamellæ.

Development.—The chief nucleus is said to appear in the sixth month of fœtal life. We have twice seen it earlier,—once at about the fourth month. An epiphysis for the back of the bone and the posterior plantar tubercles appears from the seventh to the tenth year. It begins to fuse by fifteen, completing the process in a year or so.

THE CUBOID.

The cuboid[1] is a six-sided bone, flattened from above downward, interposed between the calcaneum and the fourth and fifth metatarsal bones. It is important to remember that the dorsal surface faces almost as much outward as it does upward. The **dorsal surface**, slightly rough, has the following outline: an oblique *posterior border* against the calcaneum, which, though most often convex, may be concave, sinuous, or straight; a short *outer* concave one; an *internal* one, at first straight when against the scaphoid, and slanting outward when against the external cuneiform; and an *anterior* one, slanting outward and backward. The **plantar surface**

FIG. 434.



Right cuboid. *A*, inner aspect; *B*, posterior, outer, and inferior surfaces.

has essentially the same shape, only the angle between the posterior and inner borders is drawn out. Owing to the oblique position of the bone, this fits into the upper inner angle of the anterior surface of the calcaneum. Just below this angle is a prominence, the *plantar tubercle*. A thick, rounded, oblique ridge, the *promontory* or *tuberosity*, starting at the back of the outer border, runs forward and inward across the bone behind a groove between it and the anterior border. The tendon of the peroneus longus lies on the smooth anterior slope of the promontory, the outer

[1] Os cuboideum.

part of which is coated with cartilage. The **external surface** of the bone is deeply notched. The **internal surface** is mostly rough, but presents at about the middle an *articular facet* for the external cuneiform, broad above, narrow below, and not usually reaching the plantar surface. Commonly another smaller facet for the scaphoid is found behind this one, from which it is separated sometimes completely, but more often merely by a ridge, which makes no real interruption. The **anterior surface**, articular for the bases of two metatarsals, has an inner, an upper, and a lower border, the two latter meeting at a rounded angle externally. A faint vertical ridge, nearer the inner than the outer border, usually divides this facet into an inner oblong and an outer triangular part for the fourth and fifth bones. The curves of these articulations vary greatly: sometimes both parts are concave from above downward; sometimes both are practically plane. The **posterior surface**, entirely articular, is the complement of the front of the os calcis. The cuboid articulates with the calcaneum, the external cuneiform, the fourth and fifth metatarsal bones, often with the scaphoid, and at times with the astragalus.

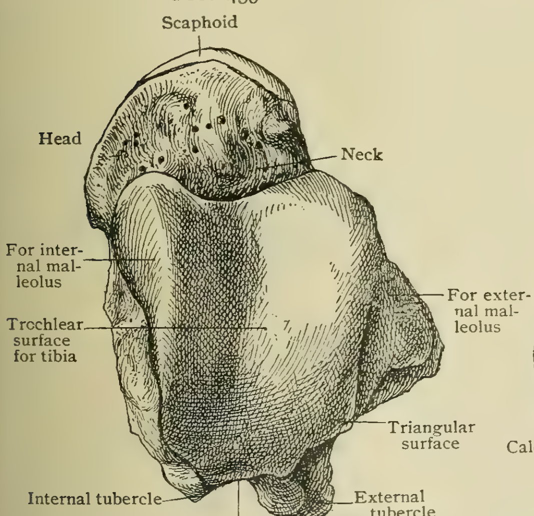
Development.—There is but one centre, appearing at about birth; in our experience, more often after than before.

For *Secondary Cuboid*, see Scaphoid.

THE ASTRAGALUS.

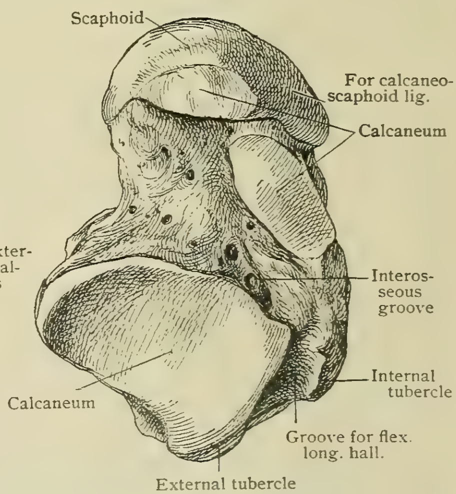
The astragalus,[1] or *talus*, is a very irregular bone devoted almost wholly to articular surfaces. It is enclosed above by the socket of the leg bones. Its main part, or body, rests on the calcaneum, and presents in front a constricted neck bearing a rounded head, projecting forward and inward into the hollow on the back of the scaphoid. The **upper surface** presents a pulley-like articular facet covering the greater part of the bone, convex from before backward, slightly concave transversely, decidedly broader in front than behind. The cartilage covering it is continued down on either side to meet the articular surfaces of the malleoli. The inner border

FIG. 435.



Right astragalus from above.

FIG. 436.



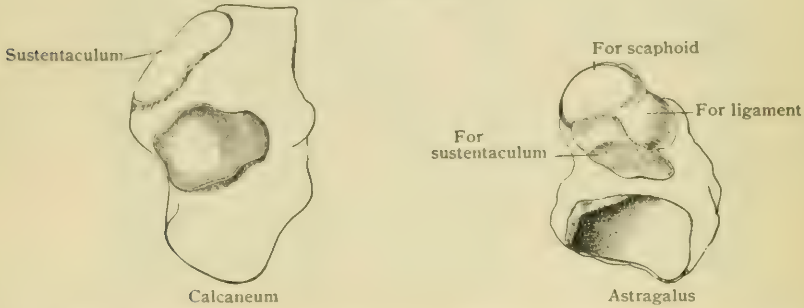
Right astragalus from below.

of the upper articular surface is distinct, but generally not sharp; the outer, which reaches higher, is better defined in the region just anterior to its middle, but behind on the dry bone it seems rounded. A very well-marked bone shows (what is very striking in the freshly opened joint) that this blunted edge is really a narrow triangular area belonging to the superior surface, broadest behind, made apparently by the pressure of the posterior tibio-fibular ligament from the external malleolus to

[1] Talus.

the back of the tibia. A much smaller similar surface is found at the front, made by the corresponding anterior ligament. The direction of the anterior border of the articular surface is very uncertain. It usually projects forward at the outer end, the rest being either transverse, posteriorly concave, or oblique. Just anterior to it is a deep transverse hollow on the upper surface of the neck, which receives the edge of the tibia in extreme dorsal flexion of the foot. The posterior border of the articular surface is also of uncertain shape. Its inner end is usually somewhat farther back than the outer. Behind it two rough *tubercles* project backward, slanting down to

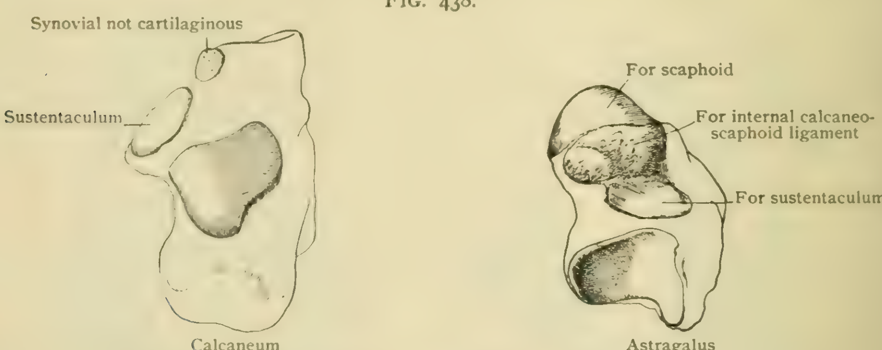
FIG. 437.



Type of calcaneo-astragaloid joint with an undivided anterior articular facet on calcaneum.

a posterior sharp edge. Between them is a deep groove for the tendon of the flexor longus hallucis, running obliquely downward and inward. The outer tubercle, which is much the larger, is sometimes separated by a suture from the rest of the bone, and is then known as the *os trigonum*. The inner tubercle may be barely distinguishable. This region behind the superior articular facet is sometimes described as the posterior surface of the bone. The **external surface** of the body shows the triangular facet for the outer malleolus, concave from above downward,

FIG. 438.



Type of calcaneo-astragaloid joint when anterior facet on calcaneum is not only divided but has front portion rudimentary.

with the lower end projecting outward, plane or convex from before backward. This is bounded before and behind by a rough strip, with a hollow at the upper ends for the front and back bundles of the external ligament of the ankle. The **internal surface** has at the top a narrow curved facet for the inner malleolus, with a concave lower border, deepest in front and pointed behind. A part of the internal lateral ligament is inserted into a hollow below it. The **inferior surface** of the body presents a four-sided facet, concave in the line of its long axis, which is oblique, corresponding to that of the greater surface on the top of the calcaneum. In front of and parallel to this is a deep *groove* for the interosseous ligament, expanding at the outer end into a triangular hollow on the under side of the **neck.** This is a

constricted portion, much broader transversely than vertically, connecting the head with the body. It often presents a groove along the upper and inner aspect near the articular surface of the head for the insertion of the ligament passing to the scaphoid. The **head,** which points forward and inward, is articular in front and below. The **anterior surface,** which fits into the hollow on the back of the scaphoid, is vaguely oval, with its long axis running downward and inward. The upper edge, parallel with this, is nearly straight. The articular surface of the head extends onto the under side, reaching to the deep groove separating the neck from the posterior facet for the calcaneum. On a fresh bone the cartilage shows the following facets, which are less well marked on a macerated one : a facet on the front of the head to fit into the scaphoid ; one on the lower and inner side to rest on the anterior articular facet of the top of the calcaneum ; one partly between these, which in the dried bones would be free, appearing between the sustentaculum and the scaphoid, but in life resting on the inferior calcaneo-scaphoid ligament, which is partly covered with cartilage and elsewhere with synovial membrane, forming a part of the socket. The cartilage on this surface is distinguished by its thinness. These facets are modified according to the arrangement of those on the calcaneum. If there be but one long anterior facet on both sustentaculum and on the end of the body of the calcaneum, the facet on the head for the anterior facet of the calcaneum reaches that for the concavity of the scaphoid in front, leaving internally a triangular interval between the two, occupied by the facet for the ligament (Fig. 437). In the other extreme (Fig. 438), where the anterior facet on the calcaneum does not reach beyond the sustentaculum, the area of the head resting against the ligament completely separates the two others and plays on that part of the calcaneum where the anterior articular cartilage should be. Finally, when the anterior facet on the calcaneum is divided into two, the corresponding facet may be completely subdivided by an interruption of the cartilage, or in less marked forms there may be merely a ridge breaking the surface into two, but without separation ; such a ridge is often found even when the opposed articular surface is not divided. The lines, however, on the head of the astragalus do not strictly correspond to the boundaries of these surfaces. The astragalus articulates with four bones,—the tibia, fibula, calcaneum, and scaphoid.

Development.—The nucleus probably appears at about the seventh month of fœtal life. When the os trigonum occurs, that implies another centre for the external tubercle and the part of the articular surface under it.

The deviation of the axis of the neck from that of the long axis of the bone varies considerably among individuals, but, nevertheless, changes during development. In the adult the angle varies from 0 to 24°, the mean of forty-three bones being 12.32°. In the fœtus (presumably at term) the angle ranges from 17.5° to 45.5°, the mean of twenty-two bones being 35.76°.[1]

THE SCAPHOID.

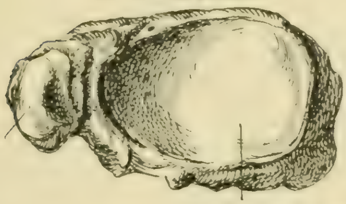
The scaphoid,[2] or *navicular*, may be compared to a disk, concave behind where it fits onto the head of the astragalus, convex in front where it rests on the three cuneiform bones. It is thinner at the outer end, where it touches the cuboid, than at the inner, where it presents the tuberosity. The **superior, or dorsal, surface** is long transversely. Its posterior border is regularly concave, the anterior slightly scalloped, presenting two small points projecting forward on either side of the middle cuneiform. When in position the highest point on the scaphoid is behind that bone. The greater part of the dorsal surface slants downward on the inner side of the foot. The **inferior, or plantar, surface** is rough, and in the main transversely concave. The *tuberosity* at the inner border for the attachment of a part of the tibialis posticus muscle is a knob formed by the junction of the dorsal and plantar surfaces, and projecting downward chiefly into the sole of the foot. The end of the knob is sometimes distinct from the scaphoid, and is known as the *tibiale externum.*

[1] C. L. Scudder: Congenital Talipes Equino-Varus, Boston Med. and Surg. Journ., vol. ii., 1887. Parker and Shattock : The Pathology and Etiology of Congenital Club-Foot, London, 1884.

[2] Os naviculare pedis.

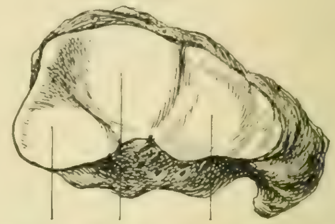
Its identity is quite evident in cases in which, though fused, it projects as a hook. It may be represented by the sesamoid bone in the tendon of the tibialis posticus. Near the outer end of the plantar surface there is almost always a slight projection by the side of the cuboid which may be very much developed, extending to near the notch in front of the sustentaculum of the calcaneum, in which case it is known as the *secondary cuboid*. The **external surface** is narrow and rough, resting against the cuboid, with which it articulates in about half the cases by a facet near the dorsum, which rarely extends far towards the sole.[1] The **posterior surface** is concave, in the main oval and completely articular. Usually the regularity of the lower border is interrupted near the outer part by the external knob of the plantar surface. If this be much developed the shape of the posterior surface is changed from oval into quadrilateral, but it is always articular throughout. The **anterior surface** is slightly convex and entirely articular, except when the process just mentioned is so large as to appear below it. The articular surface is divided into three

FIG. 439.



Right scaphoid from behind, proximal aspect.

FIG. 440.



Right scaphoid from in front.

facets, in the main triangular, corresponding to the outline of the bases of the three cuneiform bones. The character of these facets is not constant : the inner is usually convex and the outer concave.

The scaphoid articulates with the astragalus, the three cuneiform bones, often with the cuboid, and exceptionally it touches or joins the calcaneum. The *secondary cuboid*, above alluded to, has but once been seen isolated, although we have met with one foot in which it seemed possible that it might have been distinct earlier. It is fused with either the cuboid or the scaphoid, but apparently much more frequently with the latter, in which it occupies the position above described, lying at the weak part of the inferior calcaneo-scaphoid ligament.

Development.—It is generally held that ossification begins in the fourth or fifth year, but, according to Gegenbaur, it begins in the first. The *tibiale externum* exists as a separate cartilage at the second month of fœtal life. Usually this fuses with the rest, but it may have a centre of its own.

THE THREE CUNEIFORM BONES.

These wedge-shaped bones, placed between the scaphoid and the three inner metatarsals, and abutting externally on the cuboid, form an important part of the transverse arch of the foot. The thin edge of the internal cuneiform, which is much the largest, points up, that of the others down. The middle cuneiform is the smallest and shortest, so that the second metatarsal bone lies in a mortise between the inner and outer.

THE INTERNAL CUNEIFORM.

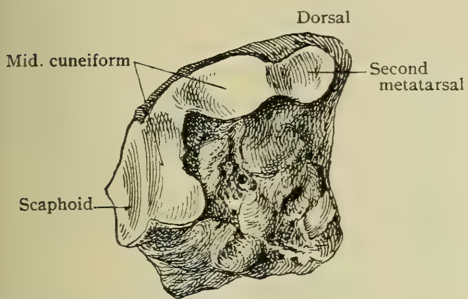
The internal cuneiform,[2] besides the proximal and distal surfaces, has an internal, an external, and an inferior. The **posterior, or proximal surface,** rounded below and pointed above, is slightly concave and wholly articular. The **anterior, or distal, surface,** also articular, is kidney-shaped, with the notch in the outer border. The **inner surface** has a small ridge in its distal half, pointing upward, which is the

[1] Pfitzner: Morph. Arbeiten, Bd. vi., 1896.

[2] Os cuneiforme primum

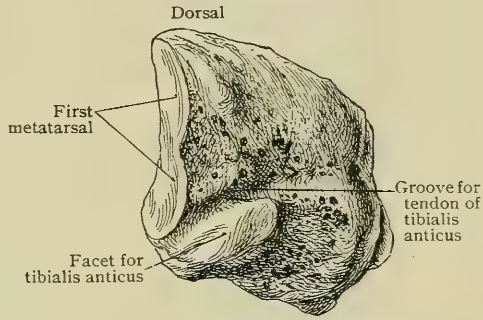
highest part of the bone, but almost the whole of this surface is on the inner side of the foot. Its outer border runs obliquely forward and outward with a sinuous course till it reaches the end of the middle cuneiform, when it turns forward. It has a short concave posterior border for the scaphoid and a long, nearly straight one for the first metatarsal bone. It passes without a sharp boundary into the lower surface. It is crossed by a faint groove, which exceptionally is deep, running obliquely downward and forward to a smooth swelling for a bursa under the tendon

FIG. 441.



Right internal cuneiform, outer aspect.

FIG. 442.



Right internal cuneiform, inner aspect.

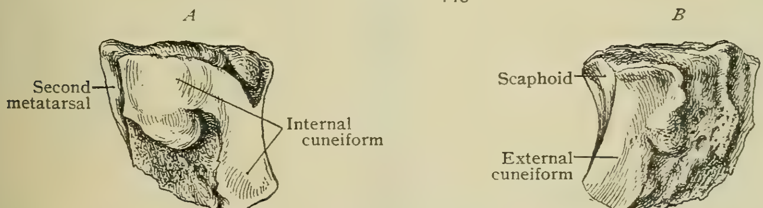
of the tibialis anticus just before its insertion. The **inferior surface,** rough and round, has a tubercle near the proximal end for a part of the tibialis posticus. The **external surface** is mostly rough, with a smooth articular strip for the middle cuneiform following its upper and posterior border. The internal cuneiform articulates with the scaphoid, middle cuneiform, and first and second metatarsal bones.

Development.—A centre appears in the third year. Very exceptionally it is double, and the bone is divided by a suture into two,—a dorsal and a plantar.

THE MIDDLE CUNEIFORM.

The middle cuneiform[1] has a sharp ridge below and an oblong surface above. The latter, or **superior surface,** is very little longer than broad. The lateral borders of this surface have an outward inclination. The inner of them corresponds to the proximal part of the outer border of the first cuneiform. The outer border, for its proximal two-thirds, rests against the external cuneiform, beyond which there is a small space between the bones. The proximal side of this surface is a little convex and the distal about straight. The **posterior surface,** wholly articular,

FIG. 443.



Right middle cuneiform. *A*, inner aspect; *B*, outer aspect.

is slightly concave. It is triangular, with the dorsal border rounded, the outer concave, and the inner straight or slightly convex. The **anterior surface,** articular for the second metatarsal, is narrower. It has a slight convexity in the upper part in a vertical plane. The **internal surface** has an articular facet corresponding to that on the internal cuneiform and a rough depression for an interosseous ligament. The **external surface** has a facet along the hind border, broader above than below, and rarely a small one at the front lower angle, both for the external

[1] Os cuneiforme secundum.

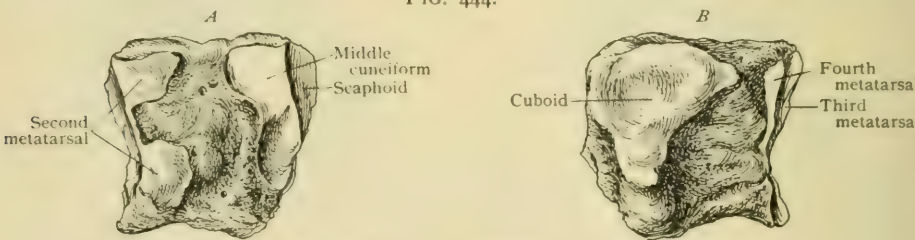
cuneiform. The middle cuneiform articulates with the scaphoid, the internal and external cuneiforms, and the second metatarsal.

Development.—One centre appears in the fourth year.

THE EXTERNAL CUNEIFORM.

The external cuneiform,[1] seen from above, is much longer than broad, with a very oblique proximal border slanting outward and backward, an anterior border running less obliquely in the same direction, an inner one close against the middle bone in its proximal third or one-half, then receding from it and extending onto the outer side of the second metatarsal, and an outer border first running forward and outward against the cuboid, and then forward not quite against it, but overlapping the fourth metatarsal. The ridge constituting the **inferior surface** does not quite reach the proximal end. The **posterior surface,** wholly articular, is oblong, with the long axis vertical, and often a little convex. The **anterior surface,** articular for the third metatarsal, is triangular and about plane. Its inner border rises higher than the outer. The **internal surface** articulates with the second cuneiform bone by

FIG. 444.



Right external cuneiform. *A*, inner aspect; *B*, outer aspect.

one or two corresponding facets, as the case may be, and has, in addition, a facet for the outer side of the base of the second metatarsal at the front upper angle, and often extending down the border; or the middle portion may be wanting. In the middle of the surface is a roughness for the interosseous ligament. The **external surface** is chiefly rough, giving origin to an interosseous ligament for the cuboid; at the upper proximal angle is a large facet for the same bone, and at the distal upper angle there may or may not be a small one for the side of the fourth metatarsal. The external cuneiform articulates with the scaphoid, the middle cuneiform, the cuboid, and the second, third, and fourth metatarsals.

Development.—Ossification begins in the first year.

The Intercuneiform Bone.—On the dorsum there is a little pit which we have called the *intercuneiform fossa*, situated between the proximal portions of the internal and middle cuneiform bones, usually more at the expense of the latter than of the former. We have at least twice seen a separate ossicle, the *intercuneiform bone*,[2] in this fossa. The better specimen was wedge-shaped, its length exceeding one centimetre. It clearly was more intimately related to the middle than to the internal cuneiform. Pfitzner has since seen it fused with the former.

THE METATARSAL BONES.

Of these five bones[3] the first is very much the largest, although the shortest. The second is the longest, and the others of about equal length.

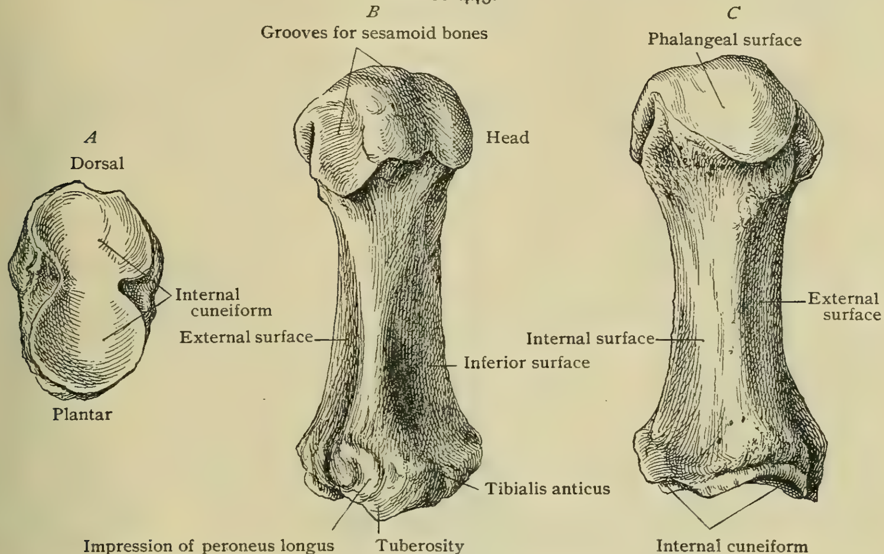
The **first metatarsal bone** has a concave *base* corresponding to the facet on the internal cuneiform, which is prolonged down into a point (*tuberosity*) rather to the outer side, on the external aspect of which the peroneus longus is inserted into a round impression. On the inner side of the base is a small *prominence* for the tibialis anticus. A smooth facet for the second metatarsal is often found on the outer side. A groove for the capsular ligament more or less perfectly encircles the

[2] Anat. Anzeiger, Bd. xx., 1902.

[1] Os cuneiforme tertium. [3] Ossa metatarsalia I-V.

base. The strong *shaft* has three sides : an *internal*, looking also upward, in the main convex ; an *external*, concave and nearly vertical ; and an *inferior*, or *plantar*,

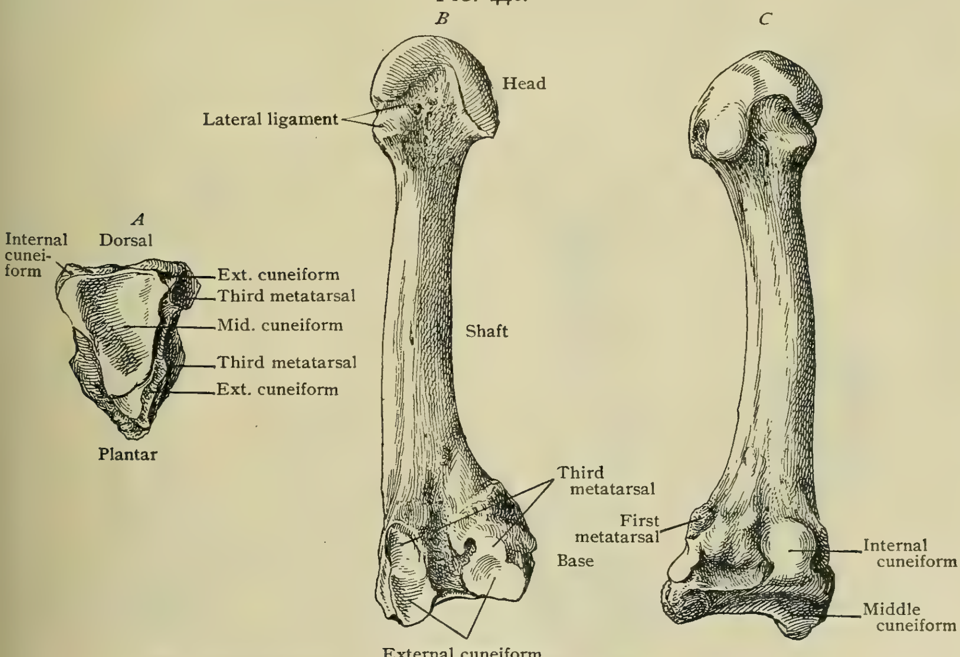
FIG. 445.



Right first metatarsal. *A*, proximal aspect ; *B*, plantar aspect ; *C*, dorsal aspect.

also concave. The borders bounding the outer surface are the most distinct. One or two nutrient foramina enter this surface, running distally. The enlarged and

FIG. 446.

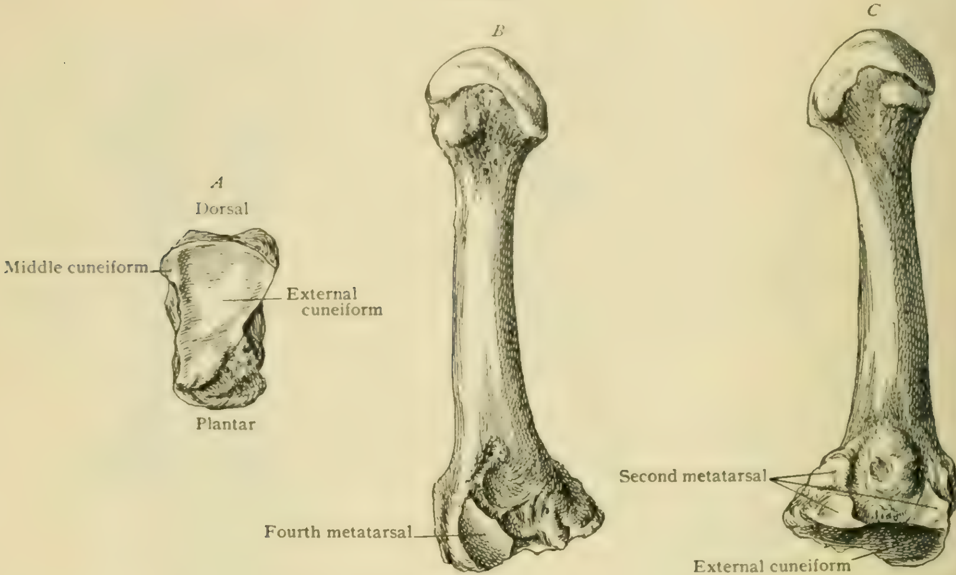


Right second metatarsal. *A*, proximal aspect ; *B*, outer aspect ; *C*, inner aspect.

rounded distal end, the *head*, is articular except at the sides, where it is flattened. The facet extends farther onto the plantar aspect, where it expands laterally. It

has there a median elevation, with a groove on either side for a sesamoid bone. There is a rough surface for ligaments on each side of the head.

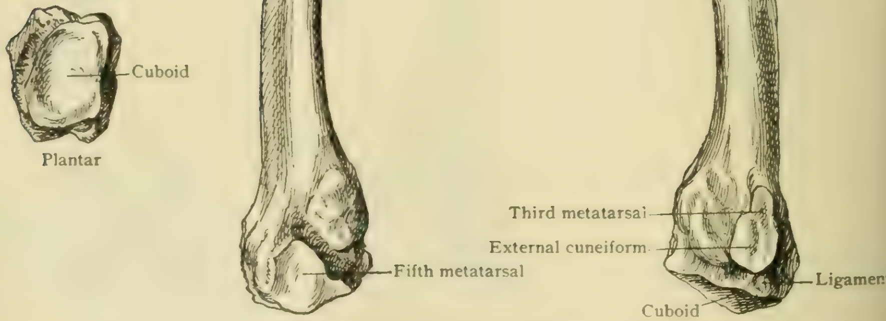
FIG. 447.



Right third metatarsal. *A*, proximal aspect; *B*, outer aspect; *C*, inner aspect.

The **four outer metatarsal bones** are distinguished by their bases. That of the **second** is concave at the end, and fits the middle cuneiform; on the *inner side* a small facet at the top meets the outside of the first cuneiform; on the *outer side* there are two, an upper and a lower, with a deep cut between each, resting

FIG. 448.

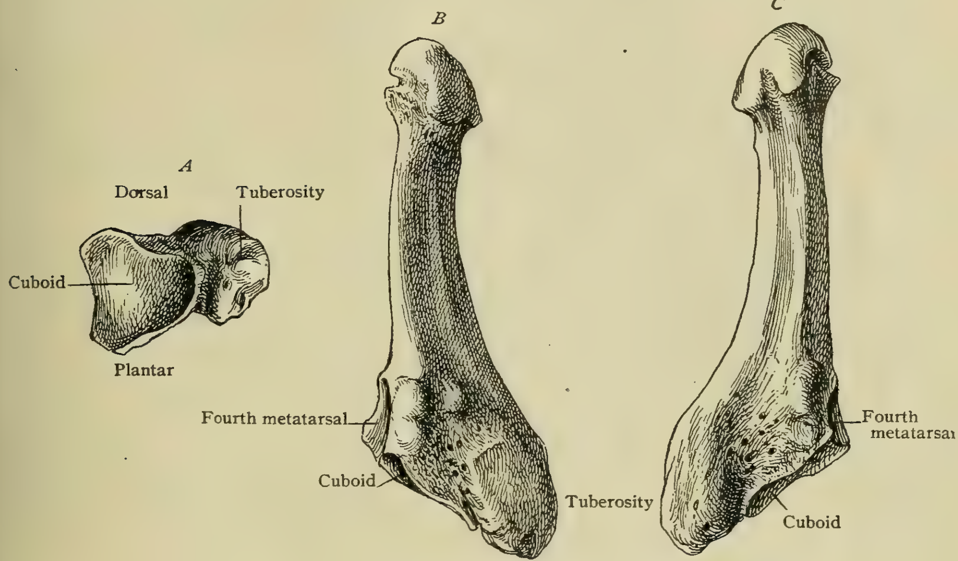


Right fourth metatarsal. *A*, proximal aspect; *B*, outer aspect; *C*, inner aspect.

on both the outer cuneiform and the third metatarsal. The occasional facet for the first metatarsal is on the shaft rather than on the end. It is often wanting on the

second when present on the first, implying the presence of a bursa rather than of a joint. The base of the **third metatarsal** fits the outer cuneiform, and is nearly plane. The posterior upper border, seen from the dorsum, is oblique, running

FIG. 449.



Right fifth metatarsal. *A*, distal aspect; *B*, dorsal aspect; *C*, plantar aspect.

outward and backward. The *inner surface* has two facets for the second, and the *outer surface* one at the top for the fourth metatarsal. The base of the **fourth metatarsal** is also oblique. It has an oblong facet for the cuboid, and a single internal one at the top for the third, which is separated from the proximal end by a rough space for the insertion of an interosseous ligament from the tarsus. There is externally a triangular facet at the upper angle for the fifth. This last facet is bounded in front by a deep groove which receives the edge of the facet on the fifth. The **fifth metatarsal** has an even more oblique base, the inner two-thirds of which bear a facet for the cuboid. The outer part is prolonged as the *tuberosity* beyond the edge of the foot, overhanging the joint. The inner side has a facet for the fourth metatarsal bone.

FIG. 450.

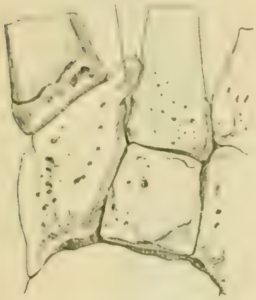
Right fifth metatarsal, inner aspect.

The **shafts** of the metatarsal bones are flattened laterally, but theoretically three-sided, like the first. The **second** has an external surface looking directly outward; a superior one at the base, which twists so as to become internal. This is separated from the former in the distal two-thirds of the shaft by a sharp ridge. The third side is internal at the base, but soon becomes inferior. The shaft of the **third** differs only slightly, the external surface looking somewhat upward and there being more of a ridge below. In the **fourth** it seems as if the proximal part of the shaft had been bent outward on its axis, so that the outer side looks more upward and the other two are less twisted. In the **fifth** this process has gone farther; the originally outer side is now the upper, separated by one border from the inner and by another from the inferior. This last border, now external, represents the one that was the inferior of the third metatarsal. The *nutrient foramina* of the four outer metatarsals are in the external surfaces, running upward. They are not very constant.

The **heads** of the metatarsal bones are compressed, like the shafts, from side to side, and have each a pair of *lateral tubercles* at the dorsal aspect of the end of the shaft, separated by a groove from the articular surface. Lateral ligaments are attached both to the tubercles and the grooves. The articular surface is oblong, extending well onto the plantar side, where it ends in two lateral prolongations, of which the outer is the more prominent. A line connecting their ends would be oblique to the shaft, especially in the outer toes.

Fig. 451.

Os intermetatarseum



Intermetatarsal bone fused with right internal cuneiform.

Fusion of the outer cuneiform with its metatarsal occurs occasionally at the plantar aspect. It is probably congenital. Pfitzner has seen it at seventeen and we at nineteen.

Development.—Centres for the shafts of the metatarsals appear towards the end of the third month of fœtal life. A proximal epiphysis for the first and distal ones for the others appear in the third year, fusing at about seventeen. Occasionally the metatarsals, especially the first, have an epiphysis at each end.

Os Intermetatarseum.—This is an occasional wedge-shaped bone found on the dorsal aspect of the foot, between the internal cuneiform and the first and second metatarsals. It may articulate with all three, or with any of them, or be attached to them by connective tissue. More often it is connected by bone with one of the three neighbors, especially with the internal cuneiform, of which it may seem to be a process (Fig. 451). It is found in some form once in ten feet (Pfitzner).

THE PHALANGES.

There are two for the great toe and three for each of the others. Although of very different proportions, they present the features which have been described for those of the hand, especially the shape of the articular surfaces. The **first phalanx** of the great toe is about as long as that of the thumb and nearly twice as broad. There is a tubercle for muscular insertion at each side of the palmar aspect of the base. The **terminal phalanx** of the great toe is also very massive. The **first,** or **proximal, phalanges** of the other toes diminish in length from within outward. Those of the **second row** are so short as to be almost cubical, although they are broader than thick. The **terminal,** or **distal, phalanges** are very rudimentary. Pfitzner[1] has shown that in about one-third of the cases the terminal phalanx of the little toe is fused with the middle one, even before birth. Presumably they never were distinct in the embryo. As he has found this condition in Egyptian mummies, certain very pessimistic views as to the degeneration in store for the human foot are probably unwarranted.

Fig. 452.

Phalanges of right second toe, plantar surface.

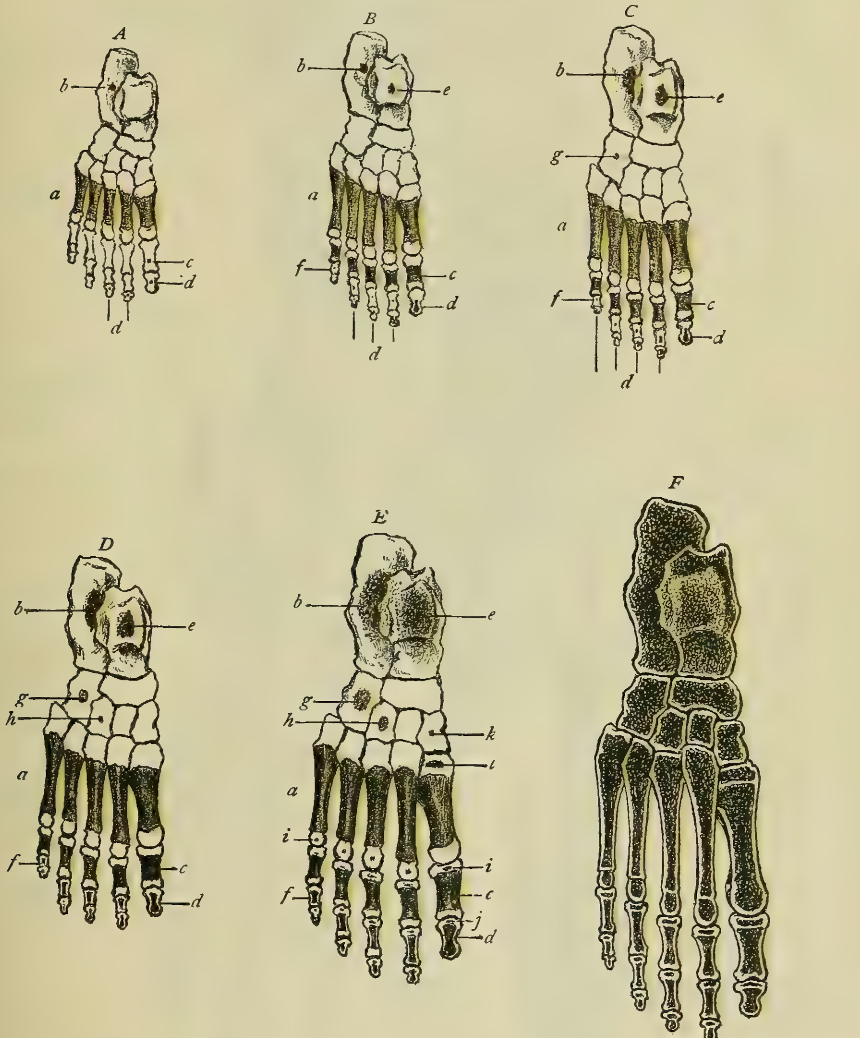
Sesamoid Bones.—Those of the first metatarso-phalangeal joint are large and constant; those of the same joint in the other toes very rare. The least uncommon are those of the fifth toe, of which the inner sesamoid is found in 5.5 per cent. and the outer in 6.2 per cent. A sesamoid of the interphalangeal joint of the great toe is found in 50.6 per cent. (Pfitzner[2]).

Development.—The first nucleus to appear is that of the distal phalanx of the great toe at the end of the third fœtal month. Those of the other distal phalanges, except the fifth, come some two weeks later. The bones of the proximal row seem to ossify rather later than the

[1] Arch. für Anat. und Entwick., 1890.
[2] Morph. Arbeiten, Bd. i.

distal ones, but this order is not constant. According to Bade,[1] the middle phalanges have begun to ossify in the eighteenth week of fœtal life, but we have found bone wanting considerably later. The process of ossification in the fourth and fifth toes is decidedly later than at the inner side of the foot. It does not begin in the middle phalanx of the fifth till near term, and we have sometimes seen no sign of it in the

FIG. 453.

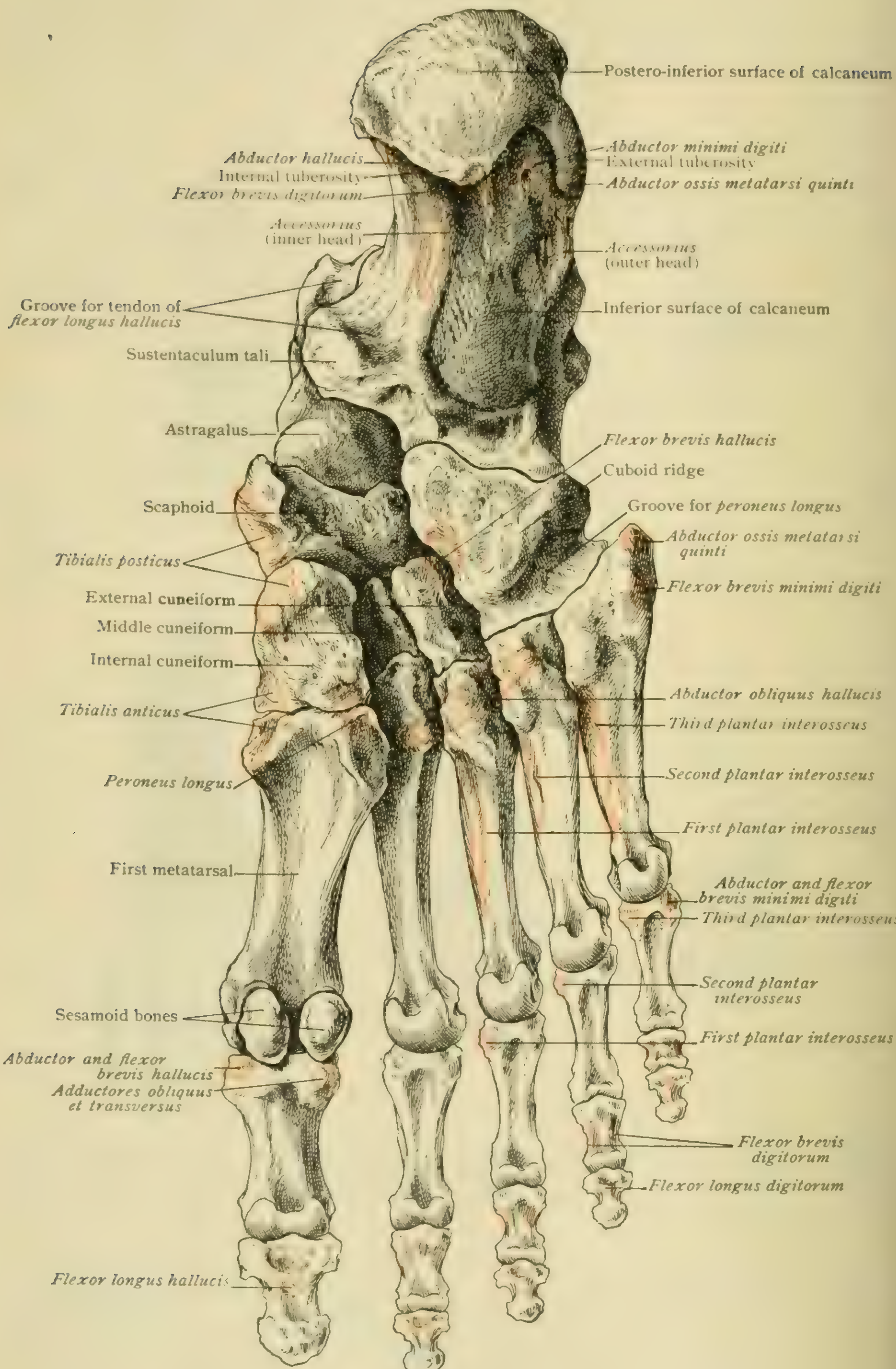


Ossification of bones of the foot. *A*, during sixth fœtal month; *B*, at eighth fœtal month; *C*, at birth; *D*, during first year; *E*, between three and four years; *F*, at about fifteen years. *a*, for shaft of metatarsals; *b*, for calcaneum; *c*, for proximal phalanges; *d*, for distal phalanges; *e*, for astragalus; *f*, for middle phalanges; *g*, for cuboid; *h*, for external cuneiform; *i*, for heads of metatarsal bones and base of first proximal phalanx; *j*, for base of first distal phalanx; *k*, for internal cuneiform; *l*, for base of first metatarsal.

fifth, and even in the fourth at birth. Proximal epiphyses appear from the fourth to the sixth year, and fuse at about sixteen. The terminal phalanges have distal caps like those of the hand. The fifth toe, according to Pfitzner, has the following peculiarities: the proximal epiphysis of the second phalanx and the centre for the shaft of the terminal one are wanting, the proximal epiphysis of the latter being greatly exaggerated.

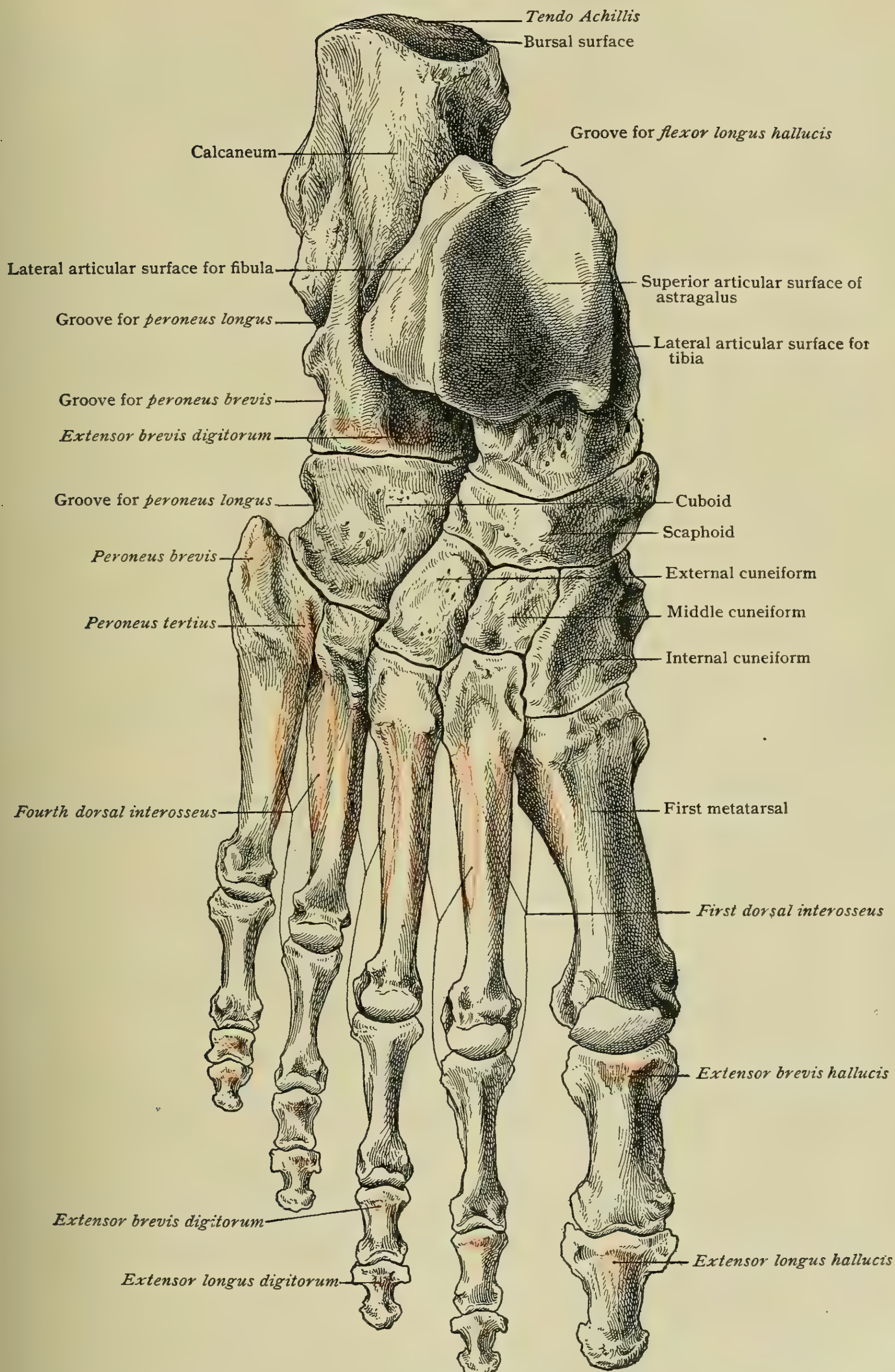
[1] Arch. für Mik. Anat., Bd. lv., 1900.

FIG. 454.



Bones of right foot, plantar aspect.

FIG. 455.



Bones of right foot, dorsal aspect.

PRACTICAL CONSIDERATIONS.

The union of the foot with the leg at a right angle, while necessitated by the erect attitude of man, makes it essential that the bones of the foot shall be so shaped and united that they may afford a basis for both support and propulsion, all prehensile function being sacrificed to those ends. Accordingly, we find the tarsus proportionately much larger, both it and the metatarsus stronger, and the phalanges much smaller and less mobile than the corresponding parts of the hand. The strength of the foot and its comparative freedom from injury, in spite of its constant exposure to traumatisms of various grades of severity, are due to the arrangement of its component bones into the form of an arch, which is well adapted not only to sustain weight and to provide leverage for motion, but also to resist and distribute excessive force received, as in falls upon the feet. The posterior pillar of the arch, composed of the os calcis and the hinder portion of the astragalus, has but one joint —the calcaneo-astragaloid—with a very limited range of motion. The action of the calf muscles upon the heel is thus applied to the elevation of the hinder pillar with the least possible expenditure of force, as there are no unnecessary movements between their point of insertion and the ankle-joint.

The anterior pillar beginning at the top of the astragalus—the summit of the arch—may be said to include practically most of the foot anterior to the ankle and to separate naturally into (1) a larger and stronger inner division consisting of the neck and head of the astragalus, the scaphoid, the three cuneiforms, and the three inner metatarsals; and (2) a weaker and smaller outer division composed of the cuboid and the remaining metatarsals.

The anterior pillar thus secures in the wide surface of the distal extremities of the metatarsal bones a broad basis of support; its inner division carries most of the weight, and is enabled to do this by the thickness and strength of the metatarsal bone of the great toe and by the parallelism of the latter with the great toe; its outer division bears less weight, but supports the inner division laterally and broadens the surface in contact with the ground. The normal foot thus rests directly upon the os calcis and the anterior extremities of the metatarsals, the outer side of the foot aiding more in preserving balance than in carrying weight.

An imperfect transverse arch—including the scaphoid, cuboid, and cuneiforms—adds to the elasticity of the foot and aids the main arch in affording a pressure-free area for the plantar vessels and nerves. Both arches depend for their integrity not only upon the shape of the bones, but also upon the fasciæ, ligaments and tendons, and to some extent upon the small plantar muscles. Still another transverse arch is formed by the bases of the metatarsal bones, and a third, but less distinct one, by their heads.

Perhaps the most accurate conception of the foot mechanically is as a semi-dome (Ellis), the whole dome being completed in well-shaped feet when the inner borders are approximated.

The epiphysis of the os calcis occupies the posterior rounded extremity of the bone, and has inserted into it the tendo Achillis. No positive clinical evidence of separation exists, but it is probable that the X-rays will show that in young persons lesions heretofore supposed to be fractures of the os calcis from muscular action are actually epiphyseal disjunctions.

The epiphyses of the remaining bones of the foot have but little surgical interest. The first metatarsal, like that of the thumb, has its epiphysis at the proximal end, and to that extent resembles a phalanx. The other four metatarsals have their epiphyses at the distal ends. All the phalangeal epiphyses are at the proximal ends. In the metatarso-phalangeal joints the synovial membrane is in close relation to the epiphyseal lines; in the phalangeal joints it is not. A knowledge of these facts may occasionally be useful in cases of disease or injury limited to a particular bone.

Fracture of the bones of the tarsus is rare, except as a result of crushing injuries or of falls from considerable heights. If the bones of the anterior pillar are broken, it is usually by direct violence, as the numerous joints and ligaments of this region render it so elastic, and so diffuse forces applied, as in jumps or falls, as effectually to

prevent fracture. The bones of the posterior pillar are broken in both ways. In falls the astragalus is apt to break about its neck,—the weakest portion; or if the foot is strongly dorsiflexed, the anterior articular edge of the tibia may act as a wedge and split it across. The os calcis may be broken between the astragalus and the ground,—compression fracture; or it may be broken behind the insertion of the inferior calcaneo-scaphoid ligament, the anterior arch being flattened by the fall, but the ligament resisting rupture. A few cases of fracture of the sustentaculum tali have been reported, the foot having been in forcible inversion, the lesser process (sustentaculum) being broken off against the edge of the astragalus. In each case this was followed by eversion and sinking of the inner border of the foot (valgus), the support given by the internal articulating surface to the astragalus having been removed.

Of the metatarsal bones, the first, although the strongest, is most frequently broken because it carries so large a proportion of the body weight and because it receives an undue share of the violence in falls associated with eversion of the foot. The fifth comes next in frequency because of its exposed position on the outer side of the foot and the added violence in cases of inversion.

Dislocation of separate bones, especially of the astragalus, is rare. It is always the result of the application of considerable crushing force, is usually associated with other injuries, and is influenced but little by anatomical factors.

Disease of the bones of the foot, and especially tuberculous disease of the tarsus, is common because of: (1) the frequency of traumatism; (2) the exposure to cold and damp and the scanty protection afforded by the superjacent tissues; (3) the remoteness from the centre of circulation and the dependent position of the part, both favoring congestions; (4) the preponderance of cancellous tissue in the bones; and (5) the difficulty in securing perfect rest, especially after minor injuries, which are those most often followed by tuberculous osteitis. It affects most frequently those bones that bear most of the weight of the body,—the os calcis, the head of the astragalus, and the base of the first metatarsal. It is more likely to remain localized when situated in the os calcis or in the hinder part of the astragalus; in the anterior portions of the tarsus the number and complexity of the synovial cavities (often intercommunicating) tend to prolong and to spread the disease. In disease of the tarsal bones—excepting the astragalus, to which no muscle is attached—the tendon sheaths in the vicinity may be involved by direct extension from the periosteum.

Any metatarsal bone may be involved in cases of "perforating ulcer," the situation of the latter being determined usually by the degree of pressure upon the sole in cases in which anæsthesia is already present; hence the frequency with which the first metatarsal is involved in this disease.

Excision of the separate bones has frequently been performed, especially of the astragalus and os calcis.

Landmarks.—On the inner side of the foot can be felt: (*a*) the ridge between the inner and posterior surfaces of the os calcis; (*b*) the tubercle of the os calcis; (*c*) the sustentaculum tali, one inch directly below the tip of the malleolus; (*d*) from one-half to three-quarters of an inch in front of the latter the head of the astragalus, very noticeable in flat-foot; (*e*) from one-half to three-quarters of an inch more anterior the prominent tuberosity of the scaphoid, the space between it and the sustentaculum being filled by the inferior calcaneo-scaphoid ligament and the tibialis posticus tendon; from the tuberosity the tendon may be traced to the back of the inner malleolus; (*f*) the internal cuneiform; (*g*) the base (one and a half inches in front of the scaphoid tuberosity), the shaft, and the expanded head of the first metatarsal; (*h*) the base of the first phalanx with the internal sesamoid bones just beneath; (*i*) the phalanges.

On the outer side are to be felt: (*a*) the ridge between the outer and posterior surfaces of the os calcis; (*b*) the external tubercle of the os calcis; (*c*) the peroneal tubercle, three-quarters of an inch below and a little in front of the tip of the external malleolus, lying between the long and short peroneal tendons; (*d*) the external surfaces of the os calcis and (when the foot is inverted) the edge of its anterior extremity, lying just above the cuboid; (*e*) the prominent base of the fifth metatarsal (about two and a half inches in front of the malleolus), the shaft, and the expanded head of that bone; (*f*) the phalanges.

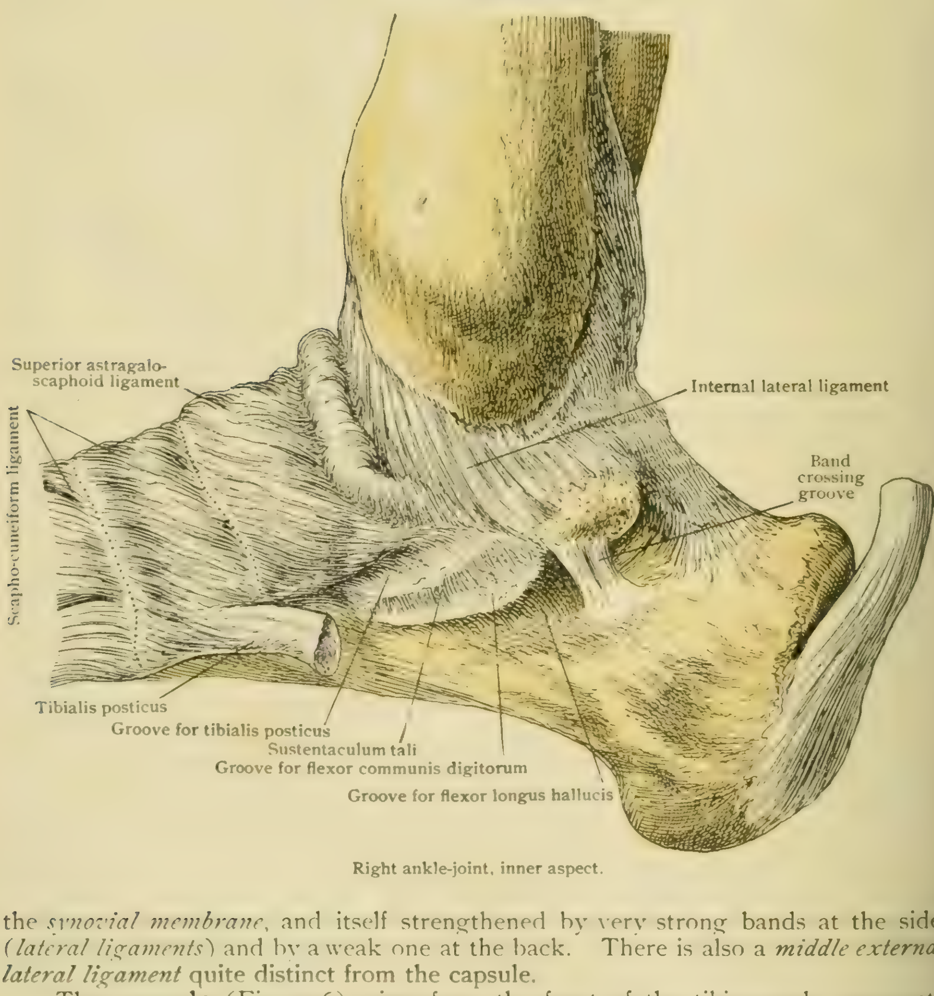
On the sole of the foot between the tuberosity of the os calcis and the heads of the metatarsals the bones cannot be felt distinctly. The internal sesamoids are directly beneath the first metatarso-phalangeal articulation.

On the dorsum of the foot, when at right angles to the leg, the bones of the tarsus form a smooth rounded convexity, with a slight elevation between its middle and inner thirds, made up of the head of the astragalus, the scaphoid, the middle cuneiform, and the second metatarsal. With the foot in full extension the head of the astragalus projects, and the extreme anterior ends of the ridges between the upper and lateral articular surfaces of that bone can be felt. The internal cuneiform at the summit of the instep is easily recognized. The other cuneiforms, the cuboid, and the metatarsals can be felt in thin feet.

THE ANKLE-JOINT.

The articulation is between the bones of the leg and those of the foot as a whole,—*i.e.*, between the tibia and fibula above and the astragalus below. It is a hinge-joint, although the mortise of the leg bones and the top of the astragalus are both broader in front than behind. The ligaments are : the *capsular*, supporting

FIG. 456.



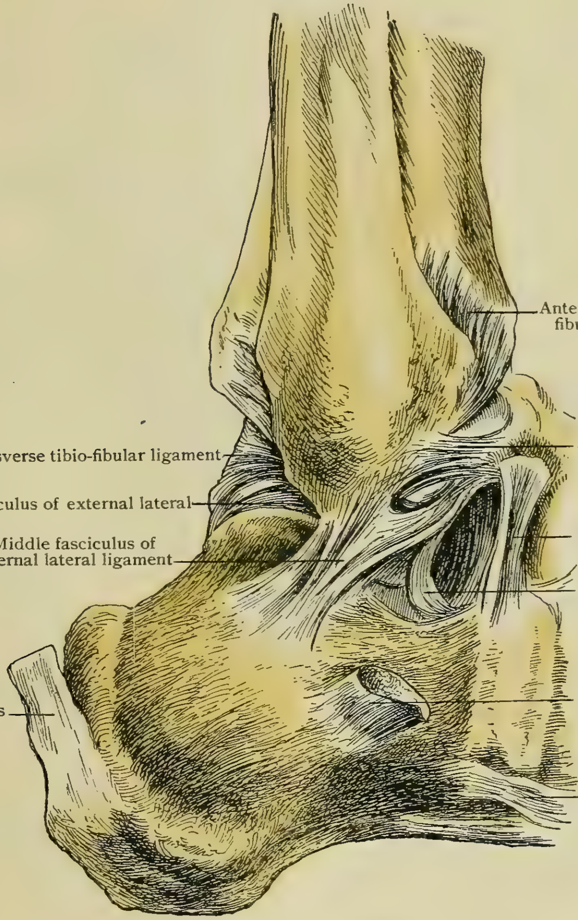
Right ankle-joint, inner aspect.

the *synovial membrane*, and itself strengthened by very strong bands at the sides (*lateral ligaments*) and by a weak one at the back. There is also a *middle external lateral ligament* quite distinct from the capsule.

The **capsule** (Fig. 456) arises from the front of the tibia nearly one centimetre above the lower border, from the edge of the anterior tibio-fibular ligament,

from the front of both malleoli at some distance from the anterior border, and from the under side of both malleolar articular surfaces. The posterior half of the superior origin is closer to the articular border both of the back of the tibia and that of the inner malleolus, but it arises from the posterior border of the outer malleolus, so as to leave a deep pocket behind the outer articular surface. The inferior insertion surrounds the articular surface on the top and sides of the astragalus, being close to the cartilage, except in front, where the distance may be one centimetre, and behind, where the separation is less. This capsule consists in front of longitudinal fibres of no great strength, often with fat between them. The posterior part of the capsule is extremely thin.

FIG. 457.



Right ankle-joint, outer aspect.

The **internal lateral**[1] or **deltoid ligament** (Fig. 456) is an extremely strong part of the capsule, arising from the notch in the posterior border and from the tip of the inner malleolus, the former portion being almost one centimetre thick, running downward and backward to the astragalus below the inner articular surface by its deeper fibres and to the sustentaculum tali by the superficial ones. The great strength of this part of the ligament is appreciated by examining it after division. The anterior part, thinner but still strong, runs to the inferior calcaneo-scaphoid ligament, and, joining the superior astragalo-scaphoid ligament, may be traced to the scaphoid. It has no line of separation from the front of the capsule.

The **external lateral ligament** (Fig. 457) is described as consisting of three bands which radiate from the external malleolus, although only two are really parts of

[1] Lig. deltoideum.

the capsule. The *anterior band*[1] (Fig. 457) passes forward and inward from the front border of the malleolus to the astragalus in front of the lateral articular surface. It is made tense in plantar flexion. The *posterior band*[2] (Fig. 457)—a very strong one—arises from the hollow on the inside of the tip of the outer malleolus and runs inward and backward to the astragalus behind the posterior outer angle of the articular surface. It is made tense in dorsal flexion. With the transverse tibio-fibular ligament it considerably strengthens the back of the capsule. The *middle band*[3] (Fig. 457), more superficial and tending to be free from the capsule, runs downward and backward to a faint tubercle on the outer side of the calcaneum. It can be made fully tense by no motion in the ankle-joint alone, but restrains certain motions of the astragalus on the calcaneum. The capsule between these bands is excessively thin.

The **synovial membrane** lining the capsule is in the main perfectly simple, following the latter; it presents, however, a prominent fold on the inside of the joint over the posterior band of the external lateral ligament, and makes something of a pouch above this, below the transverse ligament. It covers the pad of fat between the bones of the leg.

Movements.—The articulation at the ankle is essentially a hinge-joint, although not a pure one, since the fibula moves on the tibia, and the astragalus, being more closely fastened to the fibula, follows the latter in its movements; thus, the outer end of the transverse axis of rotation is subject to displacement. When the foot is midway between flexion and extension, it is possible in the dead body to impart a certain lateral motion to the astragalus, the lateral ligaments being apparently not tense; but it is highly improbable that this ever occurs during life, unless under accidental circumstances, for the muscles supplement the ligaments. As the foot moves into dorsal flexion the broadest part of the astragalus comes into the broadest part of the socket, forcing the malleoli somewhat apart. In some cases it would appear that the fibula rotates on a longitudinal axis, while the head slips backward, but both the degree and even the nature of the movement are uncertain. The foot is held firm and immovable by the spring of the bones, by the tension of the posterior ligament and of the posterior and middle divisions of the external lateral one, and especially by the strong posterior part of the internal lateral. In extreme plantar flexion the narrowest part of the astragalus is in the socket, of which the bones are in the greatest possible approximation, so that the pad of fat between them is squeezed into the joint and rests against the sickle-shaped facet of the superior surface, except that the hind end of the latter is against the posterior tibio-fibular ligament. The fold in the posterior ligament is brought against the back of the bone. The anterior ligament and the anterior parts of the lateral ones are tense. Further support is gained by the back of the astragalus below the articular facet resting against the back of the tibia so as to lock the joint. The front bands of both outer and inner lateral ligaments are tense. The action of the numerous muscles crossing the ankle is, of course, greatly to strengthen it and to prevent any giving between the bones when the ligaments are not stretched to the utmost. Moreover, the elasticity of the fibula is an important element in the mechanics of the ankle-joint, and one that makes it impossible to contrive a model that will represent the conditions actually existing.

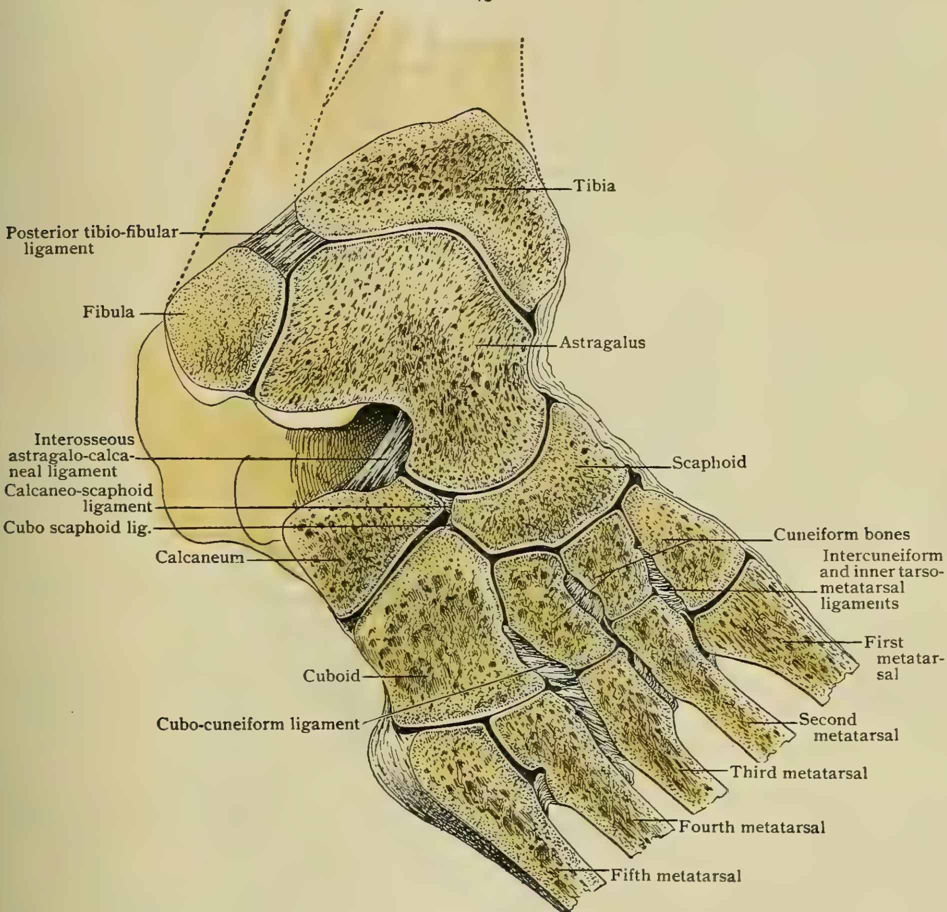
THE ARTICULATIONS OF THE FOOT.

As has been shown, the bones of the foot are so arranged (Fig. 431) that the astragalus, placed on the calcaneum, carries with it the three inner toes, while the two outer, resting on the cuboid, are more under the influence of the movements of the calcaneum. It is, however, possible for the scaphoid and cuboid to move together on the two proximal bones. The essential joints for the movements of the foot, besides the ankle-joint, are those between the *calcaneum* and *astragalus* and those between the *astragalus* and *scaphoid* and the *calcaneum* and *cuboid* respectively. The joints between the smaller bones at the front of the tarsus are mechanically unimportant, being chiefly to break shocks and to allow an indefinite giving in the arch of the foot. As certain ligaments are concerned in the protection of several

[1] Lig. talofibulare anterius. [2] Lig. talofibulare posterius. [3] Lig. calcaneofibulare.

joints, it is best first to study the ligaments of the foot all together, beginning with such as are essential parts of the framework ; then to examine the joints *seriatim;* and, finally, to discuss the motions of the foot as a whole. In the case of the smaller

FIG. 458.



Oblique section through the right foot.

ligaments it is our object to avoid pedantic attention to useless details. We shall consider first the *interosseous* ligaments, then the *dorsal*, and lastly the *plantar* ones.

THE INTEROSSEOUS LIGAMENTS.

The **astragalo-calcaneal** (Fig. 457) is a thick layer of fibres filling the groove between the two adjacent articular surfaces of each bone. At the outer part, where the groove widens, it tends to divide into two layers. A considerable quantity of fat is found in its meshes. Each side of it is lined by the synovial membrane of the joints which it separates. An occasional superficial band—the **external astragalo-calcaneal** (Fig. 457)—may be continuous with this ligament.

The **calcaneo-cubo-scaphoid** (Fig. 460) (seen by removing the astragalus and the synovial membrane covering it) is a series of short, strong fibres, collected into bundles, joining the front of the calcaneum with the outer border of the scaphoid, and by a weaker division with the inner side of the cuboid. It forms the outer part of the capsule for the head of the astragalus, reaching to the dorsum. This capsule is completed by the superior and inferior calcaneo-scaphoid ligaments.

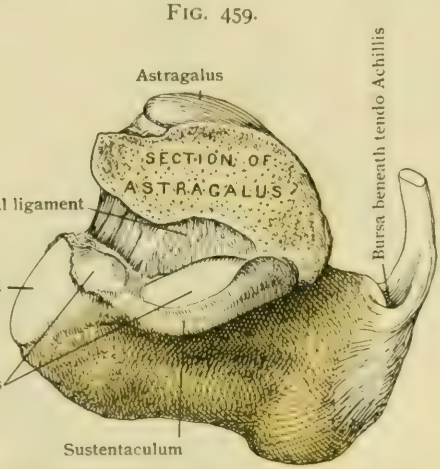
The **cubo-scaphoid** (Fig. 458) passes crosswise between these bones, close to the last ligament. Its size varies, being in inverse ratio to the articular facet between the bones it unites.

The **cubo-cuneiform** (Fig. 458) is a strong band connecting the non-articular surfaces of the cuboid and the outer cuneiform at their distal ends from the plantar to the dorsal border.

The **intercuneiform** (Fig. 458) are strong ligaments connecting the distal non-articular surfaces of these bones. That from the inner side of the middle cuneiform does not completely separate the joints before and behind it. The arrangement between the middle and outer cuneiforms is variable in this respect.

The **interosseous tarso-metatarsal ligaments** (Fig. 458) are an inner and an outer, with an occasional middle one. The *inner*, a strong band arising from the outer side of the internal cuneiform where it overlaps the second metatarsal, runs obliquely outward and forward, most of its fibres going to that bone, but a few to the

FIG. 459.



The inner part of the right astragalus has been removed.

outer side of the first metatarsal. The *outer interosseous ligament* arises from the adjacent sides of the external cuneiform and the cuboid, mingling with the fibres of the ligament already described as passing between them, and runs forward to the inner side of the base of the fourth metatarsal, to the rough surface proximal to the facet, and to the plantar half of the outer side of the third. The *middle interosseous ligament* is inconstant and small. It runs from the outer cuneiform to the second metatarsal.

The **interosseous intermetatarsal ligaments** (Fig. 458) are strong bands, best seen on section, between the bases of the four outer bones. The few fibres between the bases of the first and second do not deserve the name.

The **distal intermetatarsal ligament** is not an interosseous one, properly speaking, but is mentioned here as it is an important piece of the general framework. It is a fibrous band connecting the glenoid cartilages at the metacarpo-phalangeal joints precisely as in the hand, except that it goes to the great toe as well as to the others.

THE DORSAL LIGAMENTS.

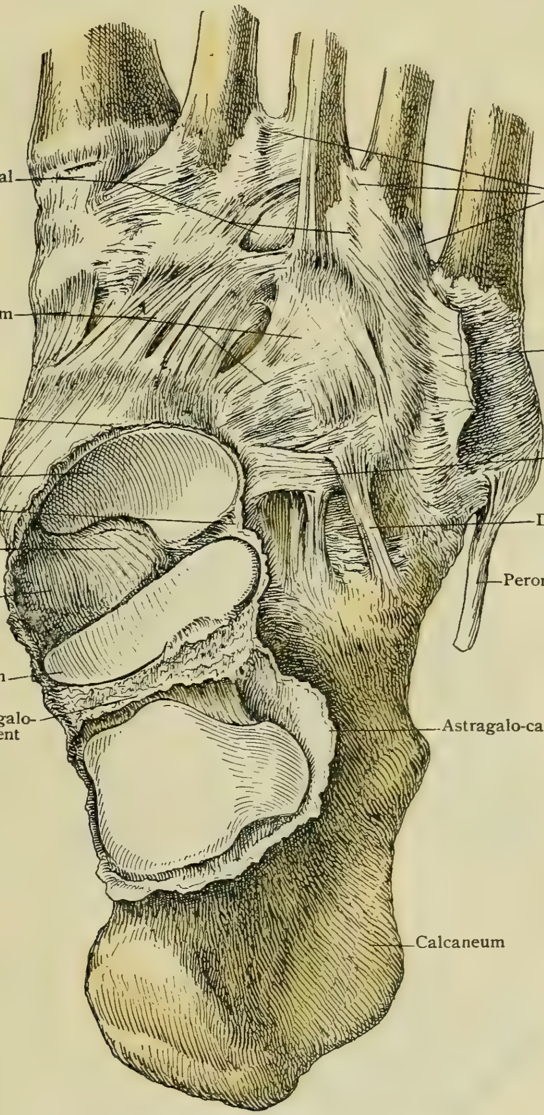
The *dorsal ligaments* of the tarsus are a number of bands of varying degrees of distinctness, all of which, in part at least, assist in forming the capsules of the various joints, although they may extend farther.

The **superior astragalo-scaphoid** (Fig. 460) might be divided into an inner part, composed of fibres running from the inner side of the former bone to the inner and dorsal aspect of the latter, and into a dorsal part, running from the margin of the head of the astragalus forward, with an inclination either inward or outward.

A series of well-marked but not strong ligaments radiate forward and outward from the scaphoid (Fig. 460): three **dorsal scapho-cuneiform** and one **scapho-cuboid ligament.**

The **dorsal calcaneo-cuboid ligament** (Fig. 460) is a thin band of little note. The interosseous calcaneo-cubo-scaphoid reaches the dorsum by the part going to the scaphoid. The ligament just mentioned is sometimes continuous with it at its origin, and the two have been called by French anatomists the *Y-ligament*, to which much consequence has been ascribed. The interosseous ligament is the important one.

FIG. 460.



Upper aspect of the right tarsus, the astragalus having been removed.

The **dorsal tarso-metatarsal ligaments** (Fig. 460) are simple for the first metatarsal, being bands running from the internal cuneiform. For the others they are more irregular, and there is an interlacing with transverse dorsal ligaments between the metatarsals connecting the outer four bones and the second to the

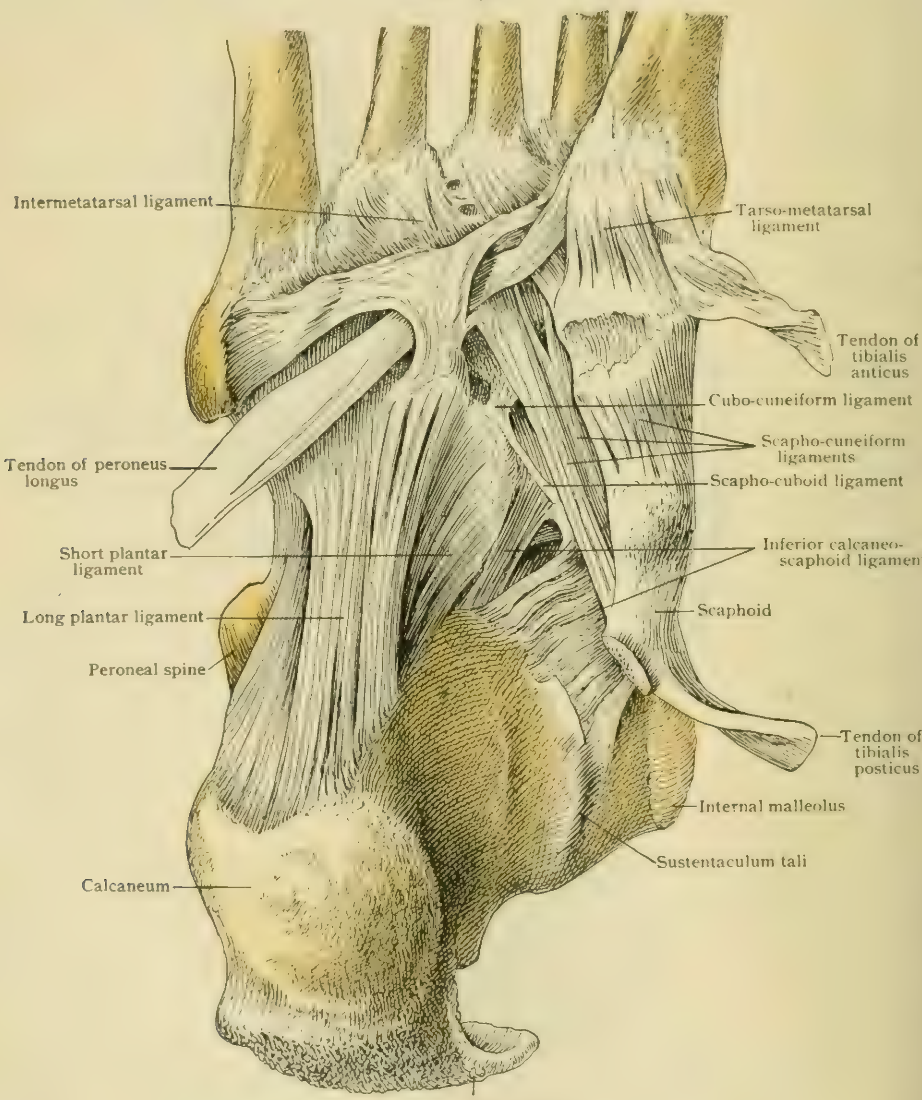
internal cuneiform. The bands over the cuboid and the two outer metatarsals are closely interwoven with the tendon of the peroneus tertius when that muscle is present. These ligaments constitute an interrupted series of bands converging forward from either side of the foot.

The dorsal ligaments are weak, and need the help of the extensor muscles of the toes to resist the strain of the strong muscles of the sole.

THE PLANTAR LIGAMENTS.

The plantar ligaments are of three kinds: (*a*) those passing from one bone to the next, and therefore nothing but thickenings of the capsule; (*b*) those passing

FIG. 461.



Right tarsus, inferior aspect.

from one bone to one or several distant ones; (*c*) and those continuous with the tendon of the tibialis posticus, which is very strong and has a far-reaching action.

The **plantar calcaneo-cuboid ligaments** are the *long* and the *short*. The former, known as the **long plantar ligament** (Fig. 461), arises from the periosteum of the under side of the calcaneum in front of the posterior tubercles, and runs forward as a flat band, at first some two centimetres broad, to the whole length of the ridge of the cuboid, except its inner end. It passes beyond this to the bases of the outer three metatarsals in a somewhat broken and weak layer of fibres forming a bridge over the groove for the tendon of the peroneus longus. The **short plantar ligament** (Fig. 461) is in part hidden by the longer, but is seen at its inner side. It arises from the anterior tubercle of the calcaneum and the bone in front of it and goes to the under side of the cuboid, between the posterior border and the ridge. The inner fibres run obliquely forward and inward.

The **inferior calcaneo-scaphoid ligament** (Fig. 460) fills the gap on the plantar side of the foot between the sustentaculum and the scaphoid. It is more or less divisible into two parts, which have a common origin from the anterior border of the sustentaculum. The inner and stronger part runs obliquely forward and inward to the lower border of the scaphoid near the tuberosity. The outer part runs more nearly straight forward to the outer part of the same border. There is generally a small interspace between them. The upper surface of the inner portion of the ligament is covered by a coating of articular cartilage completing the joint for the head of the astragalus. This cartilage is usually wanting at the anterior outer angle of the space between the bones. Beneath and to the inner side of the ligament runs the tendon of the tibialis posticus. On the inner side of the foot this ligament is continuous with a part of the superior astragalo-scaphoid and with the termination of the deltoid ligament.

The **inferior scapho-cuboid ligament** (Fig. 461) is an insignificant group of fibres.

The **inferior scapho-cuneiform ligaments** (Fig. 461) are three distinct bands, of which the inner is the broadest, the others being more cord-like, diverging from the under side of the scaphoid to the three cuneiform bones. They are all continuous with the fibres of the tendon of the tibialis posticus.

On the plantar side there is a very irregular arrangement of fibres passing from the tarsus to the metatarsus and a considerable system of oblique fibres running inward and forward from the cuboid and the fifth metatarsal to the external cuneiform and to the bases of several metatarsal bones.

The joints of the phalanges are on the same plan as in the hand and require no further description. The sesamoid bones at the tarso-metatarsal joint of the great toe are very large and connected by the glenoid ligament.

THE POSTERIOR CALCANEO-ASTRAGALOID JOINT.

This joint (Fig. 460) is separated from the anterior by the interosseous ligament, which is continuous with the capsule that completely surrounds the articulation. This capsule is in most parts weak, but is strengthened behind by the posterior astragalo-calcaneal ligament.

THE ANTERIOR CALCANEO-SCAPHO-ASTRAGALOID JOINT.

This articulation (Fig. 460) may be called a ball-and-socket joint, although the head of the astragalus is not a part of the surface of a sphere. The articular surfaces have been described with the bones. The socket is made by the anterior articular facet or facets of the calcaneum, by the posterior facet of the scaphoid, by the interosseous ligament joining these externally, and by the inferior calcaneo-scaphoid ligament, with its cartilaginous plate, which fuses on the inner side with the superior calcaneo-scaphoid and the deltoid ligament, all of which make a capsule around the head, completed by the interosseous astragalo-calcaneal ligament. A fold of synovial membrane,[1] variously developed, which may contain fibrous tissue, is generally found on the floor of this socket, extending back from the interruption of the anterior facet on the calcaneum, or from a corresponding place when it is simple, to the inferior

[1] E. Barclay Smith: Journal of Anatomy and Physiology, vol. xxx., 1896.

border of the head of the astragalus. The tendon of the tibialis posticus directly beneath and internal to the joint adds to its security.

The **motions** of the two subastragaloid joints must, of course, be considered together. They are resolved into turning on an oblique axis running through the interosseous ligament, somewhat internal to its middle, downward with something of a backward and inward inclination. Rotating on this, the posterior concave articular surface of the astragalus twists with a screw motion on the opposed surface of the calcaneum. As the back of the astragalus moves upward and outward, the head passes downward and inward in the socket. This movement is stopped by the front of the posterior articular surface of the astragalus catching in the hollow at the front of the convex surface of the calcaneum that it plays on. This is a most efficient device for locking the joint. The opposite motion is stopped by the inner posterior tubercle of the astragalus striking the back of the sustentaculum tali. In the anterior joint there is also to be considered the motion between the head of the astragalus and the scaphoid. The strong interosseous and inferior calcaneo-scaphoid ligaments do not allow much displacement of the scaphoid, but it seems that it can travel for a short distance up or down and in or out, and can therefore be slightly circumducted ; the chief motion, however, is one of rotation on the above-mentioned axis through the astragalus. Variations in the slant of the posterior articular surface of the os calcis must, of course, modify the position of the axis.

THE CALCANEO-CUBOID JOINT.

The calcaneo-cuboid joint (Fig. 458), surrounded by a capsule the inner side of which is formed by the interosseous calcaneo-cubo-scaphoid ligament, is a modification of the saddle-joint. Apart from some indefinite gliding, the nature and amount of which vary in different feet, the chief **motion** is rotation on an approximately antero-posterior axis running through the joint. It might, perhaps, be more accurately defined as a screw motion. This movement, however, is very limited. Rotation of the cuboid in a direction that would raise its outer border is checked by the interosseous and dorsal ligaments at its inner side. Rotation in the opposite direction, if not sooner arrested by the ligaments, is effectually checked by the plantar tubercle of the cuboid catching on the overhanging lip of the articular surface of the os calcis, thus locking the joint.

THE SCAPHO-CUBO-CUNEIFORM JOINT.

This articulation is a synovial cavity bounded behind by the scaphoid, extending forward to varying distances between the different bones. Thus, between the first and second cuneiforms it communicates with the joint of the second metatarsal, it is usually bounded by the interosseous ligament between the second and third metatarsals, and finally by that between the latter with the cuboid. The **motions** are very slight in each joint and of no great importance when combined. There is next to no motion of the internal cuneiform of the scaphoid and very little of the second. The external moves more freely, sliding slightly up and down. The interosseous ligaments resist the undue spreading of the transverse arch of the foot.

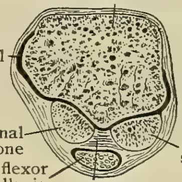
THE TARSO-METATARSAL JOINTS.

That of the **first metatarsal bone** (Fig. 458) is an independent joint with its own capsule, the interosseous ligament between the internal cuneiform and the second metatarsal shutting it off. The front of the cuneiform is convex from side to side and about plane from above down. Rarely it is subdivided into an upper and a lower compartment. It may be prolonged onto the side of the second metatarsal. An articular facet coated with cartilage is common on the outer side of the first metatarsal, but that on the second is indistinct or wanting. It seems that this is simply a bursa in most cases just beyond the joint, but they sometimes communicate. Lateral motion with this metatarsal is the most free, and there is a certain sliding up and down.

The **second tarso-metatarsal joint** opens at the inner side into the great tarsal joint, and usually with that of the external cuneiform and third metatarsal. The **motions** of these joints are slight and indefinite.

The **fourth and fifth tarso-metatarsal joints,** between the cuboid and the two outer metatarsal bones, are nearly or quite separated from the preceding by the interosseous ligament from between the outer cuneiform and the cuboid to the third and fourth metatarsals ; practically they form a distinct joint. The motion is much more free than in the others. The fourth metatarsal bone plays on the third by a facet distal to the interosseous ligament just mentioned. The fifth plays still more freely both on the fourth and on the cuboid. The **motion** is of a nature to permit the drawing of the outer side of the foot downward and inward so as to deepen the hollow of the sole. It also allows the outer metatarsals to be displaced dorsally when the transverse arch is flattened.

FIG. 462.



Transverse section through head of first metatarsal bone.

THE METATARSO-PHALANGEAL JOINTS.

These articulations in the foot are similar to the corresponding ones of the hand, the capsule including the *glenoid* and *lateral ligaments ;* the latter arise from both the tubercles and the depressions on the heads of the metatarsals. That of the great toe is large and distinguished by the large size of the *sesamoid bones*, which are interposed between the head of the metatarsal and the ground. As in the hand, there is no glenoid ligament in this joint. The *transverse metatarsal ligament* differs from that of the hand in connecting all the toes. The **motions** correspond to those of the hand, but the range of dorsal extension is greater. Lateral motion is possible only when the toes are nearly straight.

The structure and motions of the **interphalangeal joints** are as in the hand.

SYNOVIAL CAVITIES.

The following synovial cavities are found (Figs. 458, 463). (1) That of the *ankle-joint* proper ; (2) the *posterior calcaneo-astragaloid ;* (3) the *anterior calcaneo-astragaloid* completed by the scaphoid ; (4) the *calcaneo-cuboid ;* (5) the *scapho-cuneiform cuboid*, the great tarsal cavity which communicates with the joints at the bases of the second and third metatarsals by a passage at the inner side of the middle cuneiform and sometimes by one on its outer side. This may also open into the preceding synovial cavity ; (6) the joint between the *internal cuneiform* and the *first metatarsal ;* (7) that of the *cuboid* and the *outer two metatarsals.*

The arrangement of the synovial sacs about the bases of the second and third metatarsals is variable.

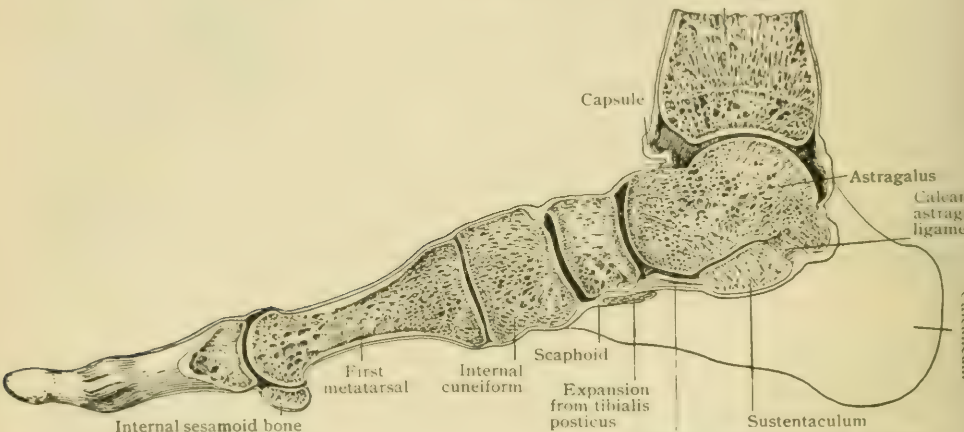
THE FOOT AS A WHOLE.

The foot is a vault which may be considered as composed of an indefinite number of arches diverging from the internal tuberosity of the calcaneum and ending in front at the heads of the metatarsals. The highest arch is that in the line of the great toe, a fact in some degree due to the sesamoid bones which are between the head of the first metatarsal and the ground. The arch at the outer side of the foot is the lowest. It is clear from this conception that transverse sections of the foot must also show an arched structure the details of which must vary with the line of section. The shape of the three cuneiforms is an essential element in this construction. This vault is, however, not rigid, but elastic and capable of considerable modification of shape under varying pressure.

In the motions of the foot the essential joints below the ankle are the *subastragaloid* and those between the *astragalus* and the *scaphoid* and the *calcaneum* and the *cuboid.*

The bones in front of the astragalus and os calcis move very much as a unit, although there may be some play between the scaphoid and cuboid and between the latter and the fifth metatarsal. The astragalus, having no muscle inserted into it, is acted on in the ankle-joint by the other bones, as is the first row of the carpus, its motions depending on the pressure it receives. When the foot is in extreme dorsal flexion, all the joints of the tarsus are locked and no motion is possible. Starting

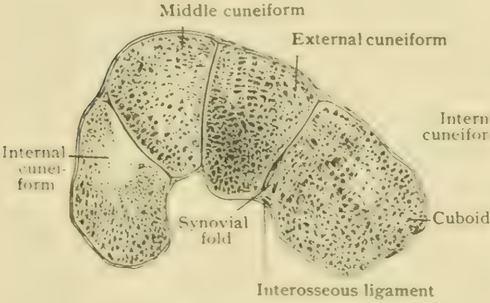
FIG. 463.



Longitudinal section through right foot in axis of first metatarsal bone.

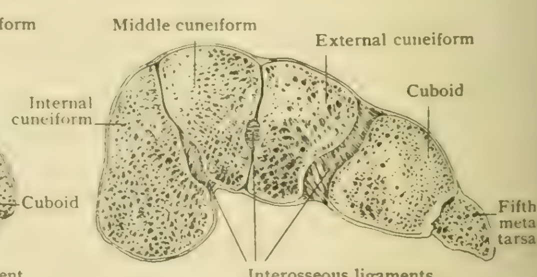
from a position of moderate flexion, the motions (excepting those of simple flexion and extension which occur in the ankle) are combinations of adduction and abduction, inversion and eversion. Adduction is generally combined with inversion, and these two motions are more extensive than the opposite ones. They practically never occur pure. Inversion and eversion occur chiefly in the joints below the astragalus, but in part in the mid-tarsal joint. Adduction and abduction are perhaps about equally divided between the two; but if the calcaneum be held by one hand and the

FIG. 464.



Transverse section through cuneiform bones of right foot, seen from behind.

FIG. 465.



Oblique section through cuneiform bones of right foot, seen from behind.

front of the foot moved by the other, it is clear that the mid-tarsal joint allows much more abduction and adduction than eversion and inversion, which therefore occur chiefly between the calcaneum and astragalus.

In the ordinary position of supporting the body it appears that the essential arch is through the calcaneum, the cuboid, the external cuneiform, joined to the latter by a firm interosseous ligament, and the third metatarsal.[1] This can be proved by

[1] H. v. Meyer: Der menschliche Fuss.

removing the first and fifth metatarsals with their phalanges and the first cuneiform bone, without impairing the stability of the foot. The fourth metatarsal may next be taken away without trouble. If the second with its cuneiform be detached with care, the arch is still reasonably firm. It is possible to preserve the arch after taking out the astragalus, and then removing the scaphoid. Although the arch still stands, it will bear little weight, the third cuneiform being inadequately supported behind ; but with the scaphoid and astragalus retained the arch is a good one. The arches depend very much for their stability on the action of the peroneus longus and the tibialis posticus, which pull against each other from opposite sides. The former is efficient in maintaining the transverse arch, the latter in maintaining both the transverse and the antero-posterior. To these should be added the plantar fascia and the muscles to the toes arising from the calcaneum. When in life the weight is equally divided between the feet, the part in contact with the ground is the heel, the outer border of the foot, the region of the heads of the metatarsals, and, separated from the rest, the balls of the toes, which bear no weight. The outer border also, as a rule, is doing no work and often does not even touch the ground, It is easy to pass a thin spatula under the head of the fifth metatarsal, and usually not hard to pass it under that of the first, thus showing that in this position they are not essential parts of the arch. When the whole or nearly the whole weight is transferred to one foot the following changes occur. The head of the astragalus turns inward, at the same time sinking under the weight of the body so as to make a prominence at the inner side of the foot. The internal malleolus follows this movement. The outer malleolus advances, but does not descend. Thus the relation of the front part of the foot to the posterior is one of abduction and eversion.[1] The weight-bearing region changes both its shape and position. The line at the outer part of the heel is the only part that remains stationary. The surface of pressure (Fig. 466) is broader at the heel and still more so at the heads of the metatarsals. The connecting strip moves inward, but becomes no broader ; sometimes it even narrows. The chief agent in resisting this change, which is greater after fatigue, is the tibialis posticus, which opposes the inner turn of the head of the astragalus which precedes its descent. When this is inadequate, the change of position is exaggerated and the foot breaks down.

Fig. 466.

Surface of pressure on sole of foot as seen through a glass plate supporting the body.

As the heel is raised, under normal conditions, the weight is transmitted through the astragalus chiefly to the bones and soft parts forming the socket for its head, the calcaneum receiving little of it. The strain comes chiefly on the ligaments securing the scaphoid, for that bone is most directly in the line of pressure, which it transmits through the front of the tarsus to the heads of the metatarsals, chiefly to the first ; but in this last respect individuals vary. Usually the region of the heads of the metatarsals narrows, the weight being borne chiefly at the inner side, but in some cases by all the heads. When the weight is borne by the toes, the foot being inverted and abducted, the locking by the catching of the plantar tubercle of the cuboid in the os calcis is an important factor of stability.

Surface Anatomy.—The malleoli are easily felt, the inner being square, the outer longer and more pointed ; the latter is the lower and the more posterior. The ankle-joint is, therefore, more easily opened from the inner side. The front lower border of the tibia is hard to examine on account of the extensor tendons ; the line of the joint is from one to two centimetres above the tip of the inner malleolus, running transversely. The general features of the os calcis can be made out. The sustentaculum is distinct and the peroneal spine can be recognized. Along the inner side, the head of the astragalus can be felt at the dorsum where it enters the hollow of the scaphoid. The tubercle of the latter is lower down and farther forward. The

[1] Lovett: New York Medical Journal, 1896.

first cuneiform and the joint behind and before it, the first metatarsal and perhaps the inner sesamoid come in order. A very moderate swelling obscures most of these points. On the outer side the joint between the calcaneum and the cuboid can be found. A little in front of this is the tuberosity of the fifth metatarsal, the only distinct landmark on the outer side. The general dorsal outline of the tarsal bones is to be recognized, but only under favorable circumstances. The dorsal surfaces of the metatarsals are distinct. The joint between the astragalus and calcaneum behind and the scaphoid and cuboid in front is sinuous: convex forward at the inner part and tending to concavity at the outer, the two ends of the line being nearly in the same transverse plane. The tarso-metatarsal joint is very oblique, running from within outward and backward. It is repeatedly irregular, the chief interruption of the direction being at the mortise of the second metatarsal between the inner and outer cuneiforms. The joints of the first phalanges with the metatarsal bones are about 2.5 centimetres behind the web of the toes.

PRACTICAL CONSIDERATIONS.

The Ankle-Joint.—Uncomplicated dislocations, inward or outward, are almost unknown because of (*a*) the close lateral approximation of the malleoli, which are held to the sides of the astragalus by the strong inferior tibio-fibular ligaments; (*b*) the further support of the lateral ligaments, especially the inner; and, (*c*) to a very minor extent, the wavy outline of the upper surface of the astragalus, which slightly resists sidewise movements.

Lateral dislocations are accordingly almost always associated with fracture of one or other of the bones of the leg, and have been sufficiently described in that connection (page 395). They are incomplete. In addition to the inward or outward movement of the astragalus it undergoes a partial rotation on an antero-posterior axis, so that its tibial surface points obliquely upward in a direction opposite to that of the displacement.

Reduction is easy and the after-treatment is that appropriate to the fracture.

Backward dislocations of the astragalus—*i.e.*, of the foot (which are etiologically forward dislocations of the tibia)—are resisted by (*a*) the shape of the upper articular surface of the astragalus, which is about one-fourth narrower behind than in front; (*b*) the corresponding shape of the irregular arch in which the astragalus rests; (*c*) the outward slope from behind forward of the lateral facets of the astragalus; (*d*) the lower level of the posterior as compared with the anterior articular edge of the tibia; and (*e*) the reinforcement of the posterior ligament by the tendon of the flexor longus hallucis. If it were not for these provisions, the frequency with which, in alighting on the ground in running or jumping, the foot is fixed and the tibia is driven forward against the weak anterior ligament would render these luxations much more common. An even more powerful leverage is produced in the same direction when, the foot being fixed, a fall backward thrusts the lower end of the tibia forward. As it is, the backward far exceed in frequency the forward luxations because, although the above-mentioned anatomical factors favor the latter, the weight of the body is scarcely ever brought upon the limb in such a direction and with such force as to induce them (Humphry).

In backward luxation the tibia rests upon the scaphoid and cuneiform, the anterior ligament is ruptured, and the posterior and lateral ligaments are lacerated. The foot is shortened from the lower anterior edge of the tibia to the web of the great toe, the heel is lengthened, the tendo Achillis describes a marked curve backward, and the depressions on either side of it are exaggerated.

Sprains of the ankle, on account of its position, where, in lateral twists, it can receive through the leverage of the whole lower extremity the weight of the entire body, are more common than of any other joint.

This force is nearly always applied through eversion or inversion (abduction or adduction) of the foot, usually the former, and the injury consists in laceration of the fibres of a lateral ligament with strain of some of the tendons in relation to the malleoli, and bruising and pinching of loose synovial membrane. More rarely extreme dorsiflexion will injure the posterior ligament and the posterior portions of

the lateral ligaments (which limit that movement), and further injury may be done to the synovial sac or to the periosteum or to the bones themselves by the forcible impact of the anterior articular edge of the tibia upon the astragalus. Sprain from hyperextension (plantar flexion) is still rarer.

In sprains from abduction there may be in the severe forms a momentary slight outward subluxation of the astragalus, as the shaft of the fibula is elastic enough to permit of this without fracture.

The looseness of the synovial sac (which is said to contain normally a relatively larger amount of synovia than any joint in the body), the dependent position of the region, and the remoteness from the centre of circulation make the swelling and therefore the tension of the joint and the pain following sprain very noticeable.

Disease of the joint is frequent for the same reasons that sprains are frequent and severe.

In simple (traumatic) synovitis the swelling is marked. It appears first in front beneath the thin anterior ligament, especially towards the outer side just in advance of the lateral ligament, because there the membrane is less bound down by extensor tendons. Later the swelling extends downward towards the dorsum of the foot for an inch or more, the extensor tendons are pushed forward, and a fulness appears on either side of the tendo Achillis which, still later, extends below the malleoli. The posterior swelling is perhaps the most valuable for diagnosis, as it is not so likely as the anterior swelling to be confused with that produced by disease of tendon-sheaths or of separate bones or joints of the tarsus.

It may be remembered in this connection that the general shape of the swelling in ankle-joint disease is, rudely, like that of an "anklet,"—horizontal,—while the swelling of teno-synovitis is more or less vertical in direction.

No early distortion of the foot is produced, as the capacity of the joint is but little influenced by position; but later the calf muscles are apt to overcome the anterior tibial group and to draw up the heel, causing "pointing" of the toes.

Tuberculosis is common, and is unfavorable in its course because of the anatomical conditions above recited, the proximity of the numerous tendon-sheaths, the complex synovial sacs of the tarsus, and the large amount of cancellous tissue in the neighboring bones, and also because of the difficulty of securing complete rest and at the same time keeping up the general health.

Excision is rarely performed, and is unsatisfactory; but *arthrectomy*, done through longitudinal incisions in front of both malleoli, and with division of the malleoli themselves, or removal of the astragalus, if it is diseased, has been followed by good results. If the astragalus is to be removed and the malleoli spared (which is often desirable on account of the proximity of the epiphyseal lines), the lateral ligaments will have to be divided. By one or other of these plans ample access to the interior of the joint can be obtained. Syme's amputation is, however, preferred by many surgeons, if ankle-joint disease is at all extensive.

The horizontal line of the ankle-joint is about half an inch above the tip of the internal malleolus and therefore an inch above the tip of the external malleolus.

The Joints of the Tarsus, Metatarsus, and Phalanges.—Dislocations of the astragalus—tibio-tarsal dislocations—have been described in connection with the ankle-joint.

Subastragaloid dislocations—i.e., of the calcaneum and scaphoid from the astragalus—are almost always either inward and backward or outward and backward, chiefly because of the shape of the opposing articular surfaces of the calcaneum and astragalus. The upper surface of the os calcis, as it advances forward, descends suddenly from a superior to an inferior level, giving the articular processes an oblique —*i.e.*, approximately vertical—direction, to which, of course, the direction of the articular facets on the under surface of the astragalus corresponds.

It is obvious that much more resistance is offered to anterior displacement of the calcaneum than to displacement in the opposite direction, and, in fact, only two examples of forward subastragaloid dislocation have been recorded.

The astragalo-scaphoid joint is involved also, but the rounded head of the astragalus offers but little resistance to the backward or lateral movement of the scaphoid, which, moreover, is held firmly in connection with the os calcis, and carried

with it because of the greater strength of the calcaneo-scaphoid as compared with the astragalo-scaphoid ligaments. As, owing to the width of the pelvis, the obliquity of the femur, and the curve of the tibia, the weight of the body is transmitted to the astragalus in an inward direction, it would be displaced inward (*i.e.*, there would be an outward luxation of the os calcis and scaphoid) far more frequently than in the opposite direction were it not for the resistance offered by the projection of the sustentaculum and the lesser articular process on the inner side and the outward obliquity of both the processes of the posterior calcaneo-astragaloid joint. The two lateral dislocations associated with some displacement backward are, therefore, about equal in frequency. The extensive opposed articular surfaces of the os calcis and astragalus are not, as a rule, completely separated; the smaller surfaces of the astragalo-scaphoid joint are, so that the one is a subluxation, the other a complete luxation.

The ligaments uniformly torn are the interosseous calcaneo-astragaloid, the astragalo-scaphoid, and one or other of the lateral ligaments of the ankle.

In inward and backward luxation the symptoms are (*a*) shortening of the line between the mid-point of the ankle and the web of the great toe; (*b*) projection and lengthening of the heel; (*c*) inversion and adduction of the foot, the inner border shortened and concave, the outer lengthened and convex; (*d*) partial disappearance of the internal malleolus; (*e*) projection of the sustentaculum tali beneath and behind it; (*f*) projection of the external malleolus and of the head of the astragalus on the outer side of the dorsum, with yielding spaces in the soft parts beneath each. The axis of the leg, when continued downward, falls to the outer side of, or even external to, the foot. The scaphoid can be felt on the inner side of the foot. The deformity resembles that of talipes varus.

In outward and backward luxation *a* and *b* are the same; there are abduction and eversion of the foot, and disappearance of the outer and prominence of the inner malleolus; the deformity resembles that of talipes valgus.

The medio-tarsal—astragalo-scaphoid and calcaneo-cuboid—articulation usually escapes injury on account of the elasticity of the anterior pillar of the arch of the foot (into which it enters) and because of the numerous joints of the anterior tarsal and the metatarso-phalangeal regions which take up and diffuse force applied to the anterior part of the foot.

The first metatarsal bone is more frequently dislocated from the tarsus than any of the others, as, relatively to the other phalanges, are the proximal phalanx and the

FIG. 467.

Section of right foot through heads of metatarsal bones, showing support by first and fourth.

terminal phalanx of the same toe. These dislocations are nearly always upward. Dislocation of the proximal phalanx of the great toe may be as difficult to reduce as is that of the thumb. Morris thinks that the sesamoid bones may act as the anterior ligament does in the latter case,—*i.e.*, being more firmly attached to the phalanx than to the metatarsal bone, they may be torn away with the former, and by their interposition prevent reduction.

The painful affection known as *metatarsalgia* has been thought (Morton) to be due to the position of the fifth metatarso-phalangeal joint, so much posterior to the fourth that the base of the first phalanx of the little toe is opposite the head and neck of the fourth metatarsal. As the fourth and fifth metatarsal bones have greater mobility than their fellows, it was supposed that this relation afforded opportunity for

accidental compression of the branches of the external plantar nerve. R. Jones thinks that it is often a communicating branch between the fourth division of the internal plantar and the external plantar that is compressed between the bone and the ground as it passes beneath the head of the fourth metatarsal. A transverse section of the foot through the heads of the metatarsals shows that the first and fourth bear the most pressure (Fig. 467). The situation of the plantar digital nerves, superficial to and not between the bones, and the collapse of the transverse arch in most cases of metatarsalgia, broadening the intervals between the bones, but increasing pressure on the structures beneath them, support the latter view.

Flat-foot is so closely associated in its anatomical deformities with talipes valgus that it will be considered in relation with the latter, which, with the other varieties of club-foot, can best be understood after the muscles and fasciæ of the leg and foot have been described.

Disease of the tarsal joints, like that of the bones, is most frequently tuberculous in character, and is more apt to remain localized when it is situated in the posterior pillar of the main arch,—*i.e.*, in the posterior half of the calcaneo-astragaloid joint. If in front of the interosseous ligament dividing that articulation, or if in either of the mid-tarsal joints (with which it communicates), or in any of the remaining four synovial cavities, it is apt to extend much beyond its original limits. The circumstances that favor the origin (page 437) and influence unfavorably the course of bone disease in this region apply in the main to disease of the joints. In whichever tissue —bony or synovial—it originates, it is apt to spread to the other. The astragalo-scaphoid joint, on account of its superficial position and its range of motion (which is greater than that of any of the joints below the ankle), is most apt to be affected. The situation of the swelling and tenderness will usually differentiate it from ankle-joint disease (page 451). Probably on account of the diffuse infection of the abundant cancellous tissue of the tarsal bones (either primary or secondary to joint disease), remote tuberculous infection—phthisis—follows or accompanies disease of the ankle and tarsus more frequently than it does disease of any other part except possibly the wrist (Cheyne).

Gout affects peculiarly the metatarso-phalangeal joint of the great toe. In 516 cases of gout, 341 were of one or both of the great toes alone and 373 of the great toe with some other part (Scudamore). This is due to (*a*) the abundance in that region of dense fibrous tissue of little vascularity; (*b*) its remoteness from the heart, the force of the circulation being at its minimum; (*c*) the large share of the body weight which it sustains, as the anterior extremity of the main arch of the foot; (*d*) the frequency of traumatism; (*e*) the constant exposure to cold and damp; (*f*) its dependent position.

Landmarks.—The ankle-joint (*q.v.*) lies about half an inch above the tip of the inner malleolus. Syme's amputation is done through this joint, the incision being made from the tip of one malleolus to the tip of the other, and at right angles to the long axis of the foot.

The mid-tarsal joint (through which Chopart's amputation is done) runs outward from a point just back of the scaphoid tuberosity, and passes directly over the dorsum of the foot to a point a little in advance of the middle of a line between the tip of the external malleolus and the tuberosity of the fifth metatarsal.

The tarso-metatarsal joint begins at a point about one and a half inches in front of the tubercle of the scaphoid,—*i.e.*, just back of the base of the first metatarsal,—passes at first directly outward, then passes irregularly around the three sides of the mortise between the internal and external cuneiforms in which the base of the second metatarsal rests, and then slopes slightly backward to its easily recognized termination on the outer side of the foot, just behind the base of the fifth metatarsal.

Hey's amputation begins and ends at the two extremities of this joint-line, but the projection of the internal cuneiform is sawn across. In Lisfranc's amputation the joint-line is followed throughout. The metatarso-phalangeal joints lie an inch behind the interdigital web.

THE MUSCULAR SYSTEM.

Muscular Tissue in General.—Contractility, although exhibited to some degree by all living protoplasm, is possessed especially by muscular tissue, the sum of the contractions of such tissue being expressed in motion, the most conspicuous characteristic of all the higher forms of animal life. Muscular tissue represents a high specialization in which contraction takes place along definite lines corresponding to the long axes of the component cells, in contrast to the uncertain contractility occurring within other elements.

The simplest form of contractile tissue, as seen in some of the low invertebrates, is represented by elements of which the superficial part is related to the integument, the deeper being differentiated into contractile fibres. Although such *musculo-epithelial cells* may form an almost complete contractile layer, the muscular fibres do not exist as an independent tissue. The differentiation of certain cells into definite muscular tissue, however, soon appears in the members of the zoological scale, although the existence of a distinct muscular system is deferred until an adequate nervous system is developed.

In the higher animals muscular tissue appears in two chief varieties, the *striated* and *non-striated*, depending upon the respective histological characteristics of their constituent elements. The former makes up the muscles controlled by the will, and is, therefore, also termed *voluntary muscle*; the latter, which constitutes the contractile tissue within the walls of the hollow viscera, blood-vessels and other tubes, acts independently of volition, and is spoken of as *involuntary muscle*. The last named is sometimes also designated *vegetative muscle*, since the organs in which it is present are largely concerned in the nutritive processes; the term *animal* may be applied in contrast to voluntary muscle. The association of the striated muscle with response to volition and, on the contrary, of the non-striated variety with involuntary action must be accepted with certain reservations, since in some animals the development of marked striation never takes place within the fibres of voluntary muscle. There is, indeed, not a little evidence going to show that the structural differences which exist between the striated and non-striated musculature are correlated with their physiological activities, and that no fundamental distinction can be drawn between them on purely morphological grounds. Muscles which in one group of animals possess the characteristics of striated muscle-tissue may, in another group, be represented by non-striated fibres (the muscles of the œsophagus, for instance), and it seems probable that the greater portion of the voluntary cranial musculature is serially equivalent to the involuntary musculature of the trunk.

The non-striated or involuntary muscle represents a tissue less highly specialized than the striped, the latter exhibiting to a conspicuous degree histological differentiation. Constituting, in a way, a separate and intermediate group stands heart muscle, which, while beyond the control of the will, presents striated fibres; the latter occupy histologically a place between the fibre-cell of the involuntary and the elongated striated fibre of the voluntary muscle. It is desirable, therefore, to consider the simpler type of contractile tissue before examining the more complex voluntary muscle.

NON-STRIATED OR INVOLUNTARY MUSCLE.

This, the less highly differentiated variety of muscular tissue, occurs in the form of bundles and thin sheets principally within the walls of the organs and vessels, although enjoying a wide distribution, seldom presenting robust masses, and being entirely unconnected with the skeleton. Even when present in considerable amount, this tissue is usually inconspicuous, presenting a faint yellowish tint.

The distribution of non-striped muscle includes: 1. The *digestive tract*,—the muscularis mucosæ from the œsophagus to the anus and delicate bundles within the

mucosa and villi ; the muscular tunic from the lower half of the œsophagus to the anus ; in the large excretory ducts of the liver, pancreas, and some salivary glands, as well as in the gall-bladder. 2. The *respiratory tract*,—in the posterior part of the trachea, encircling bundles in the bronchial tubes as far as their terminal divisions. 3. The *urinary tract*,—in the capsule and pelvis of the kidney, ureter, bladder, and urethra.

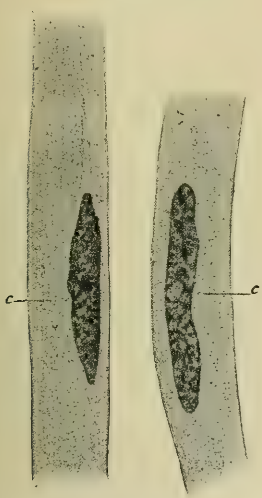
FIG. 468.

Involuntary muscle from intestine ; several isolated fibre-cells are seen above. × 200.

4. The *male generative organs*,—in the epididymis, vas deferens, seminal vesicles, prostate body, Cowper's glands, and cavernous and spongy bodies of the penis. 5. The *female generative organs*,—in the oviducts, uterus, and vagina ; in the broad and round ligaments ; in the erectile tissue of the external genitals and of the nipple. 6. The *vascular system*,—in the coats of the arteries, veins, and larger lymphatics. 7. The *lymphatic glands*,—in the capsule and trabeculæ of the spleen ; sometimes in the trabeculæ of the larger lymph-nodes. 8. The *eye*,—in the iris and ciliary body ; in the eyelids. 9. The *integument*,—in the sweat- and some sebaceous glands, as the minute erector muscles of the hair-follicles and in the skin covering the scrotum and parts of the external genitals.

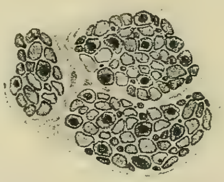
Structure.—Non-striated, unstriped, pale or involuntary muscle consists of an aggregation of structural units known as the *fibre-cells*. These are delicate spindle, often prismatic, elements which terminate in oblique surfaces at either end for contact with adjacent cells. They vary greatly in size, measuring from .050–.225 mm. in length and .003–.008 mm. in width. The muscle-cells found in the skin and blood-vessels are short (.015–.020 mm.) and broad ; those in the intestinal wall are more elongated (.215–.220 mm.) and delicate. The largest elements are encountered in the gravid uterus, in which they attain a length of .500 mm. and a breadth of .030 mm. Occasionally the cells are bifurcated at the ends, especially among the lower vertebrates.

FIG. 469.



Portions of intestinal muscle-cells, showing nucleus and centrosome (*c*). Highly magnified. (*Lenhossék.*)

FIG. 470.



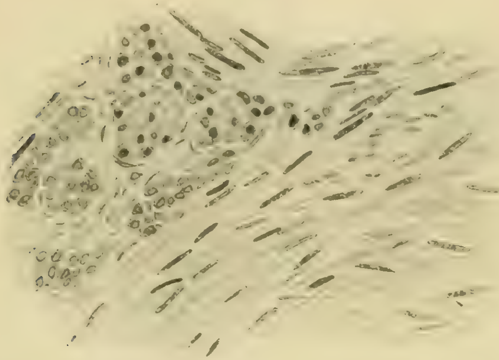
Bundles of involuntary muscle in transverse section. showing the fibre-cells cut crosswise. × 400.

More recent critical examinations of the fibre-cells have demonstrated the existence of greater structural complexity than was formerly recognized.[1] According to these later views, each fibre-cell consists of a protoplasmic mass in which lie embedded the *nucleus* and the *contractile fibrillæ*. The former is appropriately

[1] An exhaustive review of the literature and various opinions concerning the structure of unstriped muscle is given by M. Heidenhain : Ergebnisse der Anatomie und Entwick., Bd. x., 1900.

described as rod-shaped, being cylindrical with rounded ends. Its position is frequently eccentric with regard to the axis of the cell, as well as often somewhat nearer one pole than the other. The nuclei of these muscle-cells are rich in chromatin, which usually presents a reticular arrangement. Under the influence of contraction, the nuclei present more or less variation from their typical rod form. Centrosomes (Fig. 469) may be distinguished in favorable preparations lying within the cytoplasm close to the nucleus (Zimmermann, Lenhossék).

Fig. 471.

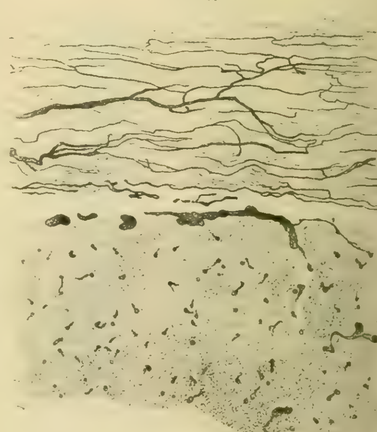


Section of uterus, showing bundles of involuntary muscle cut in various directions. × 220.

The *contractile fibrillæ* represent differentiated anisotropic threads within the cell-body, in their property of double refraction resembling the fibrillæ of striped muscle. They are most conspicuous at the periphery of the fibre-cell, where they lie closely related to the condensed *boundary zone* (Heidenhain) which forms the exterior of the fibre and fulfils the purpose of a limiting membrane or sarcolemma, although no such definite structure encloses the muscle-cell as in the case of the striated fibre. The demonstration of contractile fibrillæ within the muscle-cells of the higher vertebrates is unsatisfactory on account of the small size of the elements; in the large cells of the amphibia, especially in the huge elements of the amphiuma, their presence is readily established. Although lying usually within the periphery of the fibre-cell, the existence of a conspicuous axial fibre is seen in certain cases, as in the large isolated muscle-cells within the mesentery of newts.

The individual elements of unstriped muscle are held together by delicate membranous expansions of connective tissue prolonged from the more robust septa investing and uniting the bundles and fasciculi of the fibre-cells. On cross-section (Fig. 470), these intercellular membranous partitions appear as delicate lines between the transversely cut cells, which were formerly interpreted as tracts of cement-substance uniting the muscular elements. The appearances of intercellular bridges, described by several authors (Barfuth, de Bruyne, Werner, Bohemann, Apathy) as connecting the adjacent cells, depend probably upon the shrinkage of the latter due to the action of reagents (Stöhr, Heidenhain).

Fig. 472.



Portion of injected intestinal wall, showing arrangement of blood-vessels supplying involuntary muscle; upper longitudinally, lower transversely cut. × 50.

The **blood-vessels** supplying involuntary muscle are guided in their distribution by the septa of interfascicular connective tissue in which the larger twigs run. The latter give off minute branches which terminate in capillaries that extend between the primary bundles of the muscle-cells. The blood-supply of non-striated muscle is meagre when compared with that of the striped muscles.

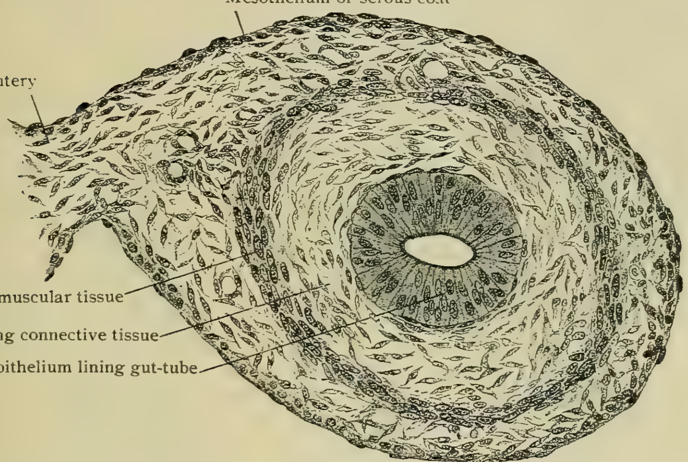
The **lymphatics** occur closely associated with the muscular tissue in localities in which the latter exists in considerable quantity, as in the wall of the stomach and intestine, the interfascicular connective tissue containing plexuses of lymph-channels,

The **nerves** supplying involuntary muscle are intimately related to the sympathetic system. The larger trunks form plexuses, in close association with microscopic

ganglia, from which delicate twigs pass between the bundles of muscle-cells. The mode of their ultimate termination is described in connection with nerve-endings (page 1015).

Development.—All muscular tissue in the higher types, with the exception of that found within the sweat-glands and the iris,[1] may be regarded practically as a derivation of the mesoblast. Reference to Fig. 34 (page 29) recalls the division of the mesoblast into the parietal and visceral layers, the latter, in conjunction with the entoblast, constituting the splanchno-pleuric folds by the union of which the gut-tube is formed. The subsequent differentiation of the visceral mesoblast contributes the layers of the wall of the digestive canal outside the epithelial structures derived from the entoblast ; in typical parts of the tube these layers are the submucous, muscular, and serous coats. The muscular tunic consists of the unstriped involuntary variety, the component fibre-cells representing specialized mesoblastic elements.

FIG. 473.



Section of developing intestinal wall, showing earliest differentiation of involuntary muscular tissue from splanchnic mesoblast. × 200.

The details of the development of the muscular tissue include condensation of the young mesoblast produced by conspicuous proliferation and increase in the cells, followed by their gradual elongation and conversion into spindle elements. These are at first short, but become extended as the tissue assumes its fully developed character. In localities in which the involuntary muscle occurs in sparingly distributed bundles and net-works the mesoblastic elements gradually assume the form of spindle-cells which for a time are inconspicuous and difficult to distinguish from ordinary young connective tissue. The formation of the muscular tissue within the walls of blood-vessels is closely identified with the intramesodermic origin of the vascular channels, the entire walls of which tubes are contributions of the middle germinal layer.

STRIATED OR VOLUNTARY MUSCLE.

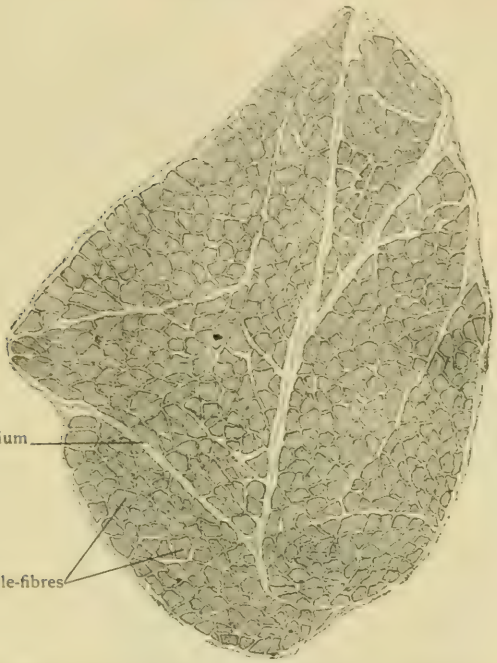
The striped muscular tissue constitutes the conspicuous masses known as the "muscles" or "flesh" attached to the bony framework of the body. These organs are also termed the *skeletal muscles*, and supply the active agents in moving the passive levers represented by the bones in producing the movements of the animal.

The muscles are usually elongated in form, and consist of aggregations of bundles of the ultimate contractile elements, the *fibres*, grouped into *fasciculi ;* upon the size of the latter depends the texture of the muscles, coarse or fine, as distinguished in the dissecting-room. In localities in which the fasciculi are of large size, as in the gluteus

[1] Szili : Archiv für Ophthalmol., Bd. liii., 1902.

maximus, the muscles are conspicuous on account of their coarse texture; a fine-grained muscle, on the contrary, is composed of small fasciculi. In addition to variations in the thickness of the fasciculi, the latter differ greatly in length irrespective of the extent of the entire muscle, since the length of the fasciculi depends largely upon the arrangement of the tendons. A long muscle may be composed of short fasciculi, since the latter may be attached to tendons which cover its opposite sides or extend within its substance as septa. In such cases, as in the rectus femoris or the deltoid, the short fasciculi run obliquely, thereby producing a pennate arrangement which often characterizes muscles of great strength. When, on the contrary, the tendons are limited to the ends of a muscle, the fasciculi are relatively long and may extend its entire length. The sartorius contains fasciculi, as well as fibres, of conspicuous extent, some bundles stretching the entire distance between the tendons.

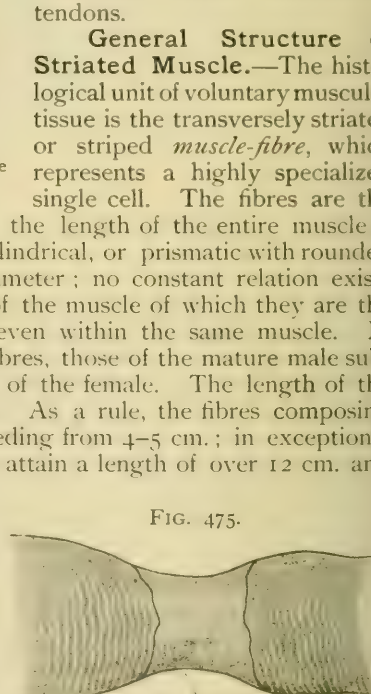
Fig. 474.



Several primary muscle-bundles in transverse section, showing the arrangement of component fibres. × 40.

General Structure of Striated Muscle.—The histological unit of voluntary muscular tissue is the transversely striated or striped *muscle-fibre*, which represents a highly specialized single cell. The fibres are the contractile elements by the shortening of which the length of the entire muscle is decreased and the force exerted. The fibres are cylindrical, or prismatic with rounded angles, in form, and vary from .01–.1 mm. in diameter; no constant relation exists between the thickness of the fibres and the size of the muscle of which they are the components, and, indeed, their diameter varies even within the same muscle. In general the limb muscles are composed of large fibres, those of the mature male subject usually exceeding the corresponding fibres of the female. The length of the muscle-fibres is likewise subject to great variation. As a rule, the fibres composing a muscle are of limited length, generally not exceeding from 4–5 cm.; in exceptional instances, however, as in the sartorius, they may attain a length of over 12 cm. and a width of from 1–5 mm. (Felix). The fibres are usually somewhat spindle-shaped, being slightly larger in the middle than at the ends, which are usually more or less pointed; blunted or club-shaped and, more rarely, branched extremities are not uncommon. Branched and anastomosing fibres occur in certain localities, as in the tongue, facial and ocular muscles.

Fig. 475.



Portion of muscle-fibre, showing sarcolemma bridging break in sarcous substance. × 370.

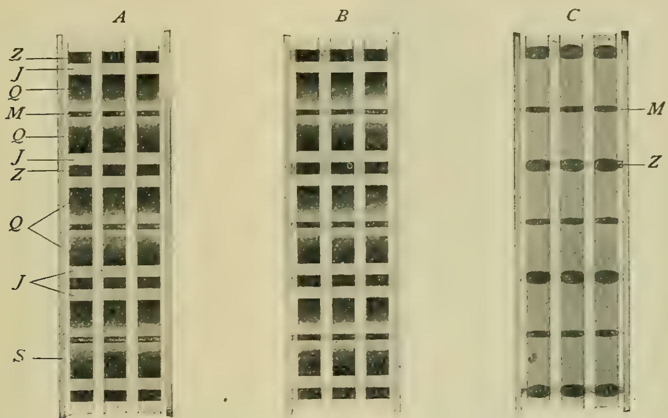
The individual fibres, each invested in its own sheath, or *sarcolemma*, are grouped into small *primary bundles*, the component fibres of which are held together by a meagre amount of connective tissue, the *endomysium*. The latter is continuous with the *perimysium* investing the primary bundles. These are associated into uncertain groups, the *secondary bundles*, which are united and enclosed by extensions and subdivisions of the general connective-tissue envelope of the entire muscle, the *epimysium*. In muscles

possessing a fine grain the secondary bundles correspond with the fasciculi, but in muscles of coarse texture each fasciculus includes a number of secondary bundles between which the ramifications of the epimysium extend. The characteristic picture presented in transverse sections of muscles (Fig. 474) illustrates the relation of the fibres to the larger groupings of the muscular elements.

Structure of the Muscle-Fibre.—Each fibre corresponds to a greatly elongated multinucleated muscle-cell, and consists of a sheath, or *sarcolemma*, and the contained *sarcous substance.*

The **sarcolemma** forms a complete investment of the fibre and alone comes into contact with the surrounding connective tissue by which the muscle-fibres are attached either to one another or to the tendinous structures upon which they exert their pull. The sarcolemma is a transparent, homogeneous, elastic membrane which so closely invests the contained sarcous substance as to be almost invisible under ordinary conditions. Being of greater toughness than the muscle-substance, it often withstands mechanical disturbance, as teasing, while the latter becomes broken; where such breaks occur the sarcous substance sometimes contracts within the sarcolemma, which at the points of fracture then becomes visible as a delicate tubular sheath stretching across the space separating the broken ends of the more friable

FIG. 476.



Diagrams illustrating structure of striated muscle-fibre. *A*, usual view; *B*, correct view, showing sustentacular septa continued across fibre from sarcolemma; *C*, septa shown after vanadium-hæmatoxylin staining. *Z*, intermediate disk (*Zwischenscheibe*); *J*, light band; *Q*, transverse disk (*Querscheibe*); *M*, median disk (*Mittelscheibe*); *S*, sarcolemma. (*After M. Heidenhain.*)

sarcous substance (Fig. 475). In teased preparations the sarcolemma is sometimes also seen projecting beyond the sarcous substance, as a coat sleeve covers the stump of an arm.

The **sarcous** or **muscular substance** within the sarcolemma in turn consists of two parts, the less differentiated passive *sarcoplasm* and the highly specialized *contractile fibrillæ* in which the active changes take place resulting in the contraction of the muscle-fibre.

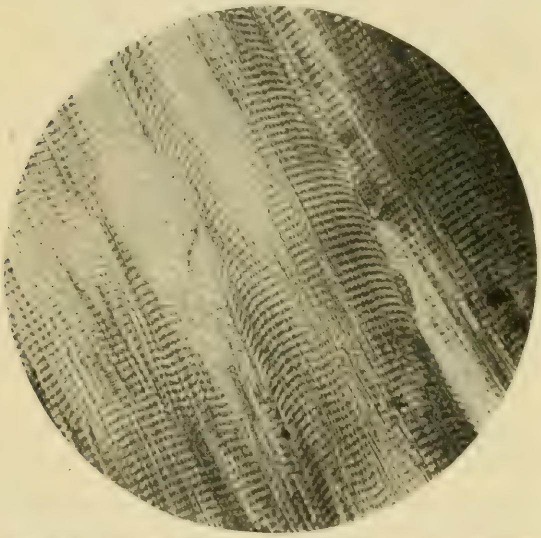
Since the highly characteristic appearance of cross-striation which distinguishes the fibres of voluntary muscle, as well as supplies the reason for its designation as striped or striated, depends upon the arrangement of the contractile fibrillæ, the details of the latter first claim attention.

The cross-striation consists of alternate dark and light bands which extend the entire width of the fibre and depend upon the differentiation of the contractile fibrillæ into segments of greater or less density. Close lateral approximation of the more dense and deeply staining segments in the fibrillæ, lying side by side within the sarcolemma, produces the dark band; the similar relation of the less dense and non-staining segments produces the impression of the light band. If it were possible to isolate the individual contractile fibrillæ, each would present the details shown in the accompanying diagram (Fig. 476). The dark, broad *transverse disk* (*Q*) of doubly refracting,

or *anisotropic*, substance is succeeded at either end by the light band (J) of singly refracting, or *isotropic*, substance. The light band is subdivided by a delicate line, the *intermediate disk* (Z), also known as *Krause's membrane*. The sequence which by repetition makes up the contractile fibrilla consists, therefore, of $Z + J + Q + J + Z$. Under favorable conditions for examination the transverse disk exhibits less density midway between its ends; this zone is traversed by a delicate line (M), the *median disk* (Hensen, Merkel) or *middle membrane* (M. Heidenhain).

The interpretation of these appearances, shown as usually seen under moderate amplification in the accompanying photograph (Fig. 477), has been the subject of much laborious investigation and vexed discussion; even at the present time authorities are far from accord as to the significance of the observed details in their relations to the architecture of the muscle-fibre. It is beyond the purpose of these pages to review the various theories concerning the ultimate structure of striped muscle;[1] suffice it to point out that, apart from the conclusions of those observers who from time to time have contended that the appearances are entirely optical and do not correspond to actual structural details, two chief views regarding the architecture of the muscle-fibre have been held. According to the one, championed by Krause, the intermediate zone is regarded as the expression of a membranous septum which stretches entirely across the muscle-fibre as an inward extension of the sarcolemma and thus subdivides the fibre into a number of minute compartments, or *contractile disks*, by the longitudinal apposition of which the entire fibre is built up. The other view, early accepted by Kölliker, regards the fibre as made up of *fibrillæ* extending the length of the fibre, the transverse cleavage into disks being secondary and artificial. The fibrillar theory as advanced by Rollet has received wide acceptance and deserves brief mention. According to this authority, the contractile fibrillæ are to be conceived as forming anisotropic rods consisting of alternating thicker and thinner segments (Fig. 478), the former corresponding in position with the broad, dark, transverse disk, the latter with the lighter band, since the meagre amount of doubly refracting substance in this zone is masked by the large quantity of isotropic sarcoplasm. Rollet recognized the intermediate disk as consisting, not of a continuous membrane, but as an interrupted line representing a row of minute beads which exist as local accumulations on the thinner segments of the fibrillæ. Rollet's conception of the fibre, therefore, included the sarcolemma containing the sarcoplasm in which the contractile fibrillæ were embedded.

FIG. 477.



Photograph of striated muscle, showing the usual appearance under moderately high magnification. × 700.

More recent investigations with the aid of improved differential stains have led to a modification of the fibrillar view in so far that the intermediate disk is to be regarded as a structure that is attached to the sarcolemma and extends between the fibrillæ. M. Heidenhain believes the median disk to be an additional membrane that likewise meets the sarcolemma at the periphery of the fibre. The later conception of muscle architecture in no wise questions the existence of the fibrillæ as the contractile elements of the fibre, but regards them as held in place by the lateral braces

[1] An exhaustive review of the literature and various opinions regarding the structure of striped muscle is given by M. Heidenhain: Ergebnisse der Anatomie und Entwick., Bd. ix., 1899.

represented by the intermediate and median bands. The foregoing diagram (Fig. 476), modified from Heidenhain, indicates the relations of the several bands to be seen in muscle when examined under the most favorable conditions. That various reagents produce marked changes in the details of the muscle-picture admits of no question ; this has been graphically represented by the last-quoted author.[1] The fact that the intermediate disk is attached to the sarcolemma is shown by the constrictions or scalloped margin in the outline of the fibre during contraction, the constrictions corresponding in position to the attachment of the membranes of Krause. The striped muscle of certain insects exhibits an additional band, the *accessory disk*, subdividing the light zone (*J*).

The distribution of the contractile fibrillæ throughout the fibre is not uniform, since the fibrillæ are grouped into bundles, the *muscle-columns* or *sarcostyles*. This arrangement is well shown in suitably prepared transverse sections of muscular tissue (Fig. 479), in which the individual fibres are seen to be made up of minute stippled areas separated by clear lines. These areas are known as *Cohnheim's fields*, and represent the transversely cut groups of contractile fibrillæ. The clear lines indicate the distribution of the sarcoplasm ; in addition to forming the net-work dividing Cohnheim's fields, the sarcoplasm separates the groups of individual fibrillæ, each muscle-column being entirely surrounded by the less highly differentiated substance.

FIG. 478.

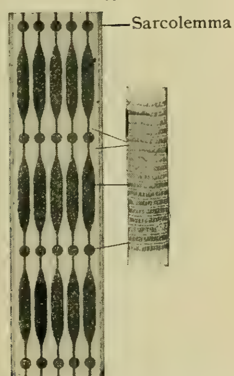
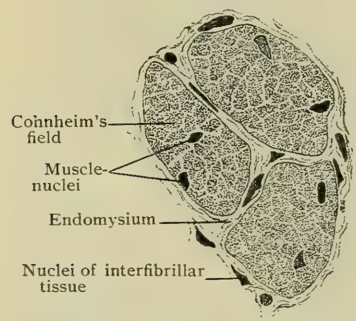


Diagram illustrating Rollet's view of structure of muscle-fibre and relations of assumed details to usual appearances of tissue.

FIG. 479.



Muscle-fibres of lizard in transverse section, showing fields of Cohnheim and muscle-nuclei. × 650.

When seen in longitudinal section, the sarcoplasm between the groups of fibrillæ appears as lines extending the entire length of the fibre, to which an inconspicuous longitudinal striation is thus imparted.

The muscle-fibre has already been spoken of as a multinucleated cell. The nuclei resulting from the division of the nucleus of the embryonal cell remain within the sarcoplasm and are termed *muscle-nuclei*. Their position in mammalian muscle is usually immediately beneath the sarcolemma ; in certain fibres, however, as those composing the semitendinosus of the rabbit (Fig. 480), and of uncertain distribution in man, the nuclei lie more deeply embedded within the sarcoplasm, therein agreeing in location with the position occupied by the nuclei in the muscular tissue of many of the lower vertebrates (Fig. 479).

Variations in the color and contractility of muscular tissue have been described by Ranvier and Krause, Klein, Grützner, and others. While the skeletal muscles are usually of a pale tint and contract energetically when stimulated, particular muscles of certain animals, as the semitendinosus and the soleus in the rabbit, possess a deeper color and contract more slowly and prolongedly under stimulation. Such *red muscles*, as they have been named, are composed of fibres which are thinner than common and possess a relatively larger amount of sarcoplasm, in which the muscle-nuclei are embedded not only immediately beneath the sarcolemma, but also in the

[1] M. Heidenhain : Anatom. Anzeiger, Bd. xx., Nos. 2 and 3, 1901.

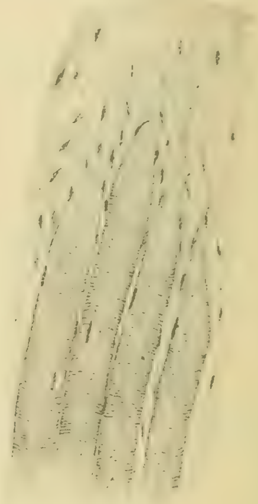
deeper parts of the fibre (Fig. 480). The longitudinal striation is also unusually conspicuous, due to the exceptional amount of interfibrillar sarcoplasm. Although not present in mammals generally in sufficient quantity to affect the appearance of entire muscles, the peculiar "red" fibres are found in many localities intermingled with the more usual pale variety. Klein has described such fibres in the diaphragm, and according to the investigations of Grützner and of J. Schaffer, it is probable that they are found in all muscular tissue upon which devolves prolonged effort. These fibres are, therefore, present in the heart, the eye muscles, and the muscles of respiration and of mastication. The red fibres must be regarded as representing a less complete differentiation of the muscle-cell and as possessing consequently a larger proportion of reserve protoplasm; they are better able to withstand the fatigue of contractions than those in which the specialization of a larger part of the cytoplasm has occurred. The pale fibres gain in rapidity of contraction at the expense of early exhaustion.

Attachment of the muscular fibres, whether to other fibres or to tendons, is accomplished by the union of the sarcolemma with the connective or tendinous tissue

FIG. 480.

Portion of the soleus muscle of the rabbit in transverse section. The more coarsely stippled fibres are of "red" muscle; they also contain nuclei within the sarcous substance. × 160.

FIG. 481.



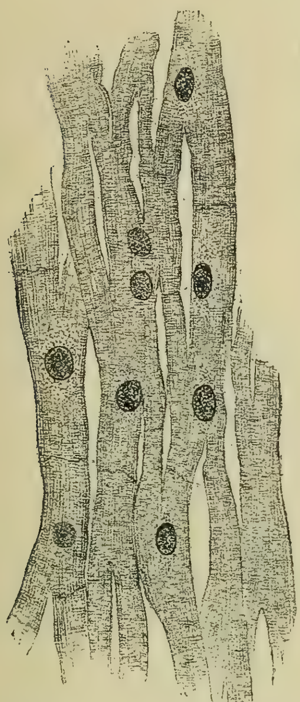
Section of tendon, showing termination of muscle-fibres. × 200.

and never by direct fusion of the connective tissue with the sarcous substance, the latter remaining completely invested by its sheath. On joining a muscle (Fig. 481), the tendon-tissue subdivides into small bundles which receive and surround the pointed ends of the muscle-fibres, the fibrous tissue becoming attached to the sarcolemma, while the areolar tissue between the tendon-bundles blends with that separating the muscle-fibres.

Cardiac Muscle.—The striped muscle of the heart, in addition to the peculiarity of being beyond the control of the will, although striated, presents certain modifications in the form and arrangement of its fibres which call for special consideration. According to the views formerly held, the histological unit of the myocardium was the branched fibre-cell (Fig. 482), by the apposition of which the sheets of muscular tissue were formed. The fibre-cell was regarded as a short branched fibre, devoid of a sarcolemma and possessing a nucleus surrounded by a considerable area of undifferential sarcoplasm. Studies of the histogenesis of cardiac muscle show that the contractile tissue arises as a continuous network, or syncytium, without cell boundaries, but provided with nuclei. The subsequent appearance of the transverse

lines, or *intercalated discs*, has been interpreted as expressing a later differentiation into fibre-cells, the cross-lines being regarded as indicating the limits of the component fibres. According to Jordan,[1] however, the intercalated discs are neither cell boundaries (Zimmermann) nor growth-zones (Heidenhain), but must be interpreted in terms of the ultimate fibrillæ, not of the whole fibre, and are due to

FIG. 482.



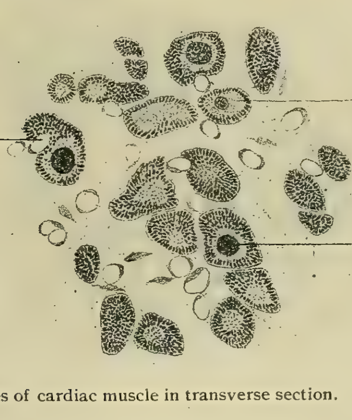
Muscle-fibres of human heart. × 375.

FIG. 483.

Diagram showing the form and arrangement of the intercalated discs. (*M. Heidenhain.*)

accumulations of anisotropic substance, associated in some way with contraction. The heart muscle possesses a large amount of sarcoplasm, as evidenced by the con-

FIG. 484.



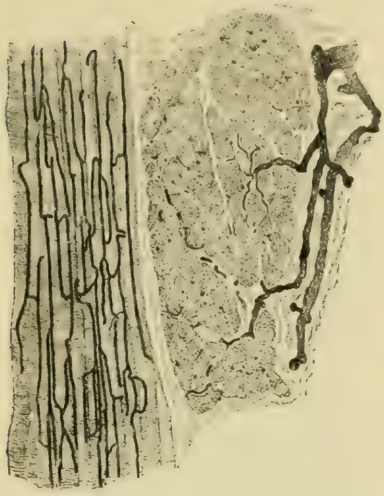
Fibres of cardiac muscle in transverse section. × 375.

siderable accumulation surrounding the nucleus, as well as the thicker strata separating the muscle-columns.

[1] Anatomical Record, vol. v, No. 11, 1911.

The **blood-vessels** of striped muscle are very numerous to insure adequate nutrition to a tissue of great functional activity. The larger arteries and accompanying veins penetrate the muscle along the septal extensions of the epimysium and divide into smaller branches which run between the fasciculi. These vessels undergo further subdivision into twigs which pass between the finer bundles of muscle-fibres and ultimately break up into the capillaries enclosing the individual fibres.

FIG. 485.



Injected voluntary muscle, showing arrangement of interfascicular vessels and capillaries. × 50.

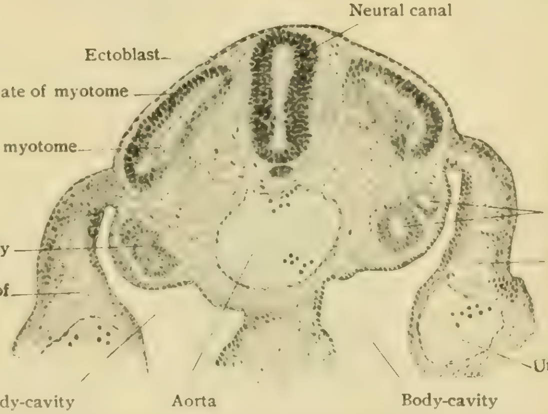
The capillary vessels of voluntary muscle form a characteristic net-work consisting of narrow rectangular meshes (Fig. 485), the longer sides of which correspond to the direction of the muscle-fibres between which they run; the shorter sides of the meshes are formed by the capillaries which extend across or may encircle the individual fibres. The capillaries supplying muscles subjected to prolonged and powerful contractions often exhibit local dilatations, which may serve for temporary reservoirs for the blood during contraction. The closeness of the capillary net-work is determined by the size of the muscle-fibres, muscles composed of fine fibres possessing the smallest vascular meshes.

The relation of the blood-vessels to cardiac muscle is unusually intimate, the capillaries not only enclosing the muscle-fibres with a rich net-work, but lying within depressions on the surface of the fibres, or even in channels surrounded by the muscular tissue (Meigs).

The **lymphatics** of striated muscular tissue are represented by the interfascicular clefts, which extend within the connective tissue between the muscle-fibres, and the more definite channels within the septa. The larger lymph-vessels formed by the confluence of those lying between the fasciculi pass to the sheath of the muscle and tendon and carry off the lymph from the muscular tissue.

The **nerves** supplying striped muscle include both motor and sensory fibres. The former terminate in specialized arborizations, the *motor nerve-endings*, which

FIG. 486.



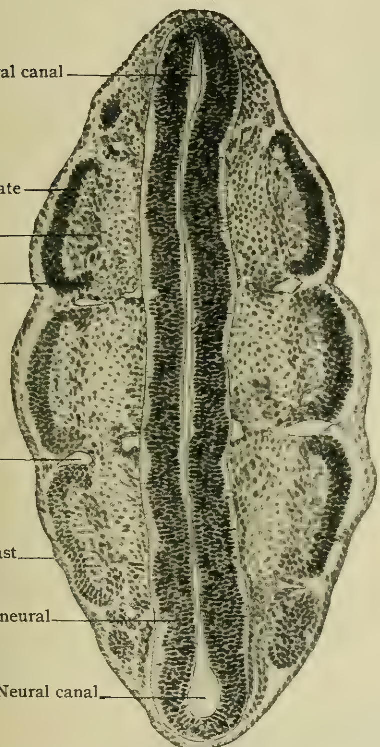
Transverse section of rabbit embryo, showing differentiation of myotomes. × 90.

are usually regarded as lying beneath the sarcolemma upon the sarcous substance. The sensory fibres are connected with the neuro-muscular end organs or *muscle-spindles*, from which the afferent nerves proceed centrally. The detailed description

of both varieties of terminations in striped muscle will be found under nerve-endings (page 1014).

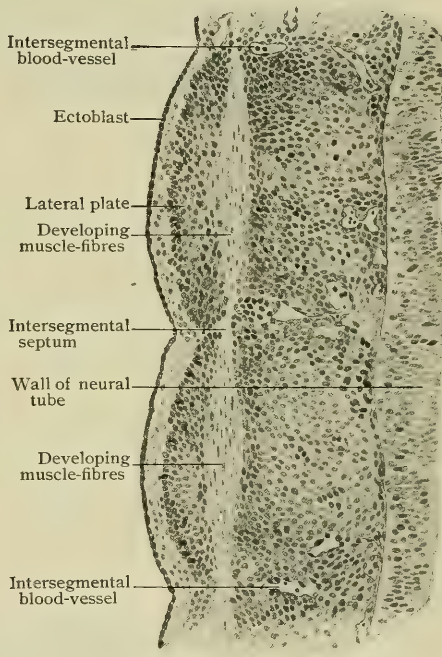
Development of Striped Muscle.—The early appearance of a series of quadrilateral segmental areas, the *somites*, within the tract of the paraxial mesoblast on each side of the neural tube has been described (page 29). Likewise the subsequent breaking up of each somite into the centrally situated sclerotome and the peripheral myotome (Fig. 34). The latter soon becomes a compressed C-shaped mass, in which the more compact lateral part is usually described as the *cutis-plate* and the medial portion as the *muscle-plate*. The histological characters of these parts of the myotome differ, the cutis-plate consisting of several layers of closely packed cells resembling epithelial elements, while the muscle-plate is composed of more loosely disposed spindle-cells, between which lie irregularly round cells, many of

FIG. 487.



Frontal section of rabbit embryo, showing myotomes. × 100.

FIG. 488.



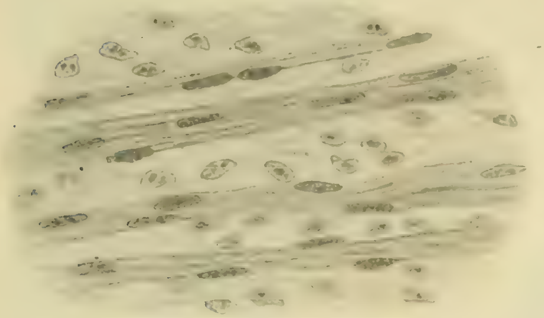
Frontal section of two myotomes of rabbit embryo, showing developing muscle. × 130.

which are actively engaged in division. The less differentiated round cells, or *myoblasts*, become elongated and transformed into the spindle-cells, the elements which are directly converted into the young muscle-fibres. The spindle-cells, at first mononuclear, rapidly increase in length, the round or oval nucleus at the same time undergoing division. In consequence the elongated muscle-cells become multinuclear. The cytoplasm of the cells early exhibits differentiation into a peripheral and a central zone. During the second fœtal month the former manifests a disposition to become fibrillar, while the central zone for a time remains undifferentiated and contains the muscle-nuclei.

On cross-section the young muscle-fibres at this stage appear as stippled rings enclosing an indifferent core surrounding the nuclei, the stippling being due to the partially differentiated fibrillæ. The latter appear first as marginal groups, but later form a continuous peripheral zone. This gradually widens and, by the close of the sixth fœtal month, the fibres composing the muscles of the upper extremity

have become fibrillar throughout their entire thickness; those of the lower extremity acquire a similar condition a month later. With the deeper extension of the fibrillæ the characteristic cross-striation appears, the nuclei migrating to the periphery of the fibre as the less differentiated cytoplasm becomes invaded. The sarcolemma appears by the time the entire fibre has become fibrillar. The sarcoplasm surrounding the nuclei of the mature fibre represents the remains of the less highly differentiated cytoplasm of the original muscle-cell; that, however, separating the muscle-columns must be regarded as the product of a secondary differentiation.

FIG. 489.

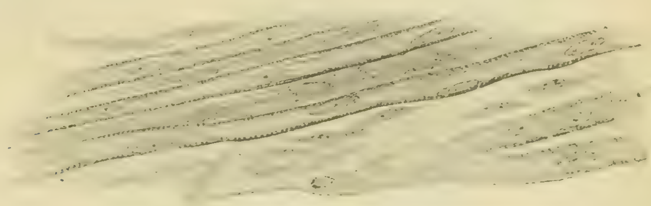


Developing voluntary muscle; the fibres are still unstriated. × 525.

The designation "cutis-plate," applied to the compact outer epithelioid portion of the myotome, expresses the relation to the integument which has been widely accepted, since this part of the myotome is generally regarded as concerned in the formation of the connective-tissue portion of the skin. This fate of the "cutis-plate" was long age denied by Balfour, who held that both layers of the myotome are concerned in the formation of muscular tissue. Kaestner[1] arrived at similar conclusions, and more recently Bardeen[2] has shown that in the pig practically the entire epithelial lamella is converted into muscle. According to this investigator, while some of the epithelial elements of the skin-plate degenerate, the greater number undergo mitosis and give rise to myoblasts which, in turn, become the spindle-cells from which the muscle-fibres are developed. The outer margin of the epithelial lamella is sharply defined by a limiting membrane formed by the adjacent cells; a somewhat similar but less pronounced boundary guards the inner contour of the lamella. The external limiting membrane persists until the conversion of the epithelioid elements into myoblasts and spindle-cells has been well established, by which time the mesoblastic tissue surrounding the myotomes has grown in between the latter and the adjacent ectoblast; it is from this source, therefore, and not from the "cutis-plate," that the connective-tissue layer of the integument is derived.

The masses of embryonal muscle, or *myomeres*, derived from the somites are early separated by the ingrowth of intersegmental septa of connective tissue which

FIG. 490.



Developing muscle-fibres in which striation is just appearing. × 375.

later support the intersegmental blood-vessels and nerves and, in the thoracic region, the costal elements, and, by the ingrowth of a connective-tissue partition, each one is further divided into a dorsal and a ventral portion, from which, in a general way, the muscles associated with the spine and the antero-lateral body-walls are derived respectively.

In this primitive condition the trunk musculature is represented by a series of

[1] Archiv für Anat. u. Phys., Suppl. Bd., 1890.
[2] Johns Hopkins Hospital Reports, vol. ix., 1900.

bands, the myomeres (Fig. 493), which consist of a dorsal and a ventral portion, and which succeed one another regularly and segmentally throughout the entire length of the trunk. The muscle-fibres of which each myomere is composed extend from the intersegmental septum in front to that behind, having thus a regular antero-posterior direction. In the lower vertebrates this condition persists with but little modification throughout life, producing the flake-like arrangement of the muscles characteristic of the fishes. In the higher vertebrates, however, numerous secondary modifications supervene, whereby the myomeres are broken up into individual muscles, their original segmental arrangement becoming at the same time greatly obscured, although it still persists in those regions in which the muscles are intimately associated with segmental skeletal structures such as the vertebræ and ribs.

These changes are of several kinds, and, as a rule, several varieties of modification coöperate in the differentiation of a muscle. Some of the more important are as follow :

1. An end-to-end fusion of several myomeres or portions of myomeres takes place, producing a muscle-sheet or band which extends uninterruptedly through several primary segments. Such a modification gives rise to muscles supplied by a number of segmental nerves ; just as many, indeed, as there are myomeres participating in the formation of the muscle. Examples of muscles formed in this way are to be seen in the musculature of the abdominal walls, the oblique muscles, the transversalis, and the rectus, for instance, being all polymeric muscles, as are also many of the longitudinal muscles of the back. Not infrequently the origin of these muscles by the fusion of portions of successive myomeres is shown, independently of their nerve-supply, by the persistence in their course of some of the intermuscular septa, these forming transverse tendinous bands traversing the muscle in a horizontal direction. Such tendinous inscriptions (*inscriptiones tendineæ*), as they are termed, occur normally in the rectus abdominis, and are also frequently found in the internal oblique, the sterno-hyoid, and the sterno-thyroid muscles.

2. A longitudinal division of the myomeres into a number of distinct and originally parallel portions may occur. Examples of this modification combined with the end-to-end fusion of the portions so formed from successive myomeres are very abundant. Thus, the rectus abdominis is the result of the splitting off of the ventral portion of a number of successive myomeres, whose remaining portions are largely represented in the oblique and transverse abdominal muscles. So, too, in the neck, the differentiation of the sterno-hyoid and omo-hyoid is due to the same process, and it has also acted in the differentiation of the various muscles of the transverso-costal group of the dorsal musculature.

3. A tangential splitting of the myomeres is again an occurrence of great frequency, producing superposed muscles, and is clearly shown in the dorsal musculature and in the ventro-lateral muscles of the thoracic and abdominal walls. It does not necessarily involve all portions of a myomere when this has already divided longitudinally, but may be confined to only certain of the parts so formed. Thus, while it affects the ventro-lateral abdominal muscles, it does not affect the rectus abdominis, this muscle representing the entire thickness of the ventral borders of a number of successive myomeres.

4. Associated with the change just described there is frequently a modification in the direction of the fibres in one or more of the superposed muscles. Primarily the fibres of each myomere have a cephalo-caudal direction,—a condition which is still retained in the rectus abdominis, for instance. In the ventro-lateral abdominal and thoracic muscles, however, the original direction of the fibres has been greatly altered, those of the superficial layer being directed in general downward and inward, those of the middle layer to a considerable extent downward and outward, while those of the deepest layer are directed almost or quite transversely,—that is to say, in a direction which is 90° different from that taken by the fibres of the myomere.

5. An exceedingly interesting modification is that which results from the migration of some of the myomeres over their successors, so that a muscle formed from certain of the cervical myomeres, for example, may in the adult condition be superposed upon muscles derived from the thoracic segments. In such cases of migration

the segmental nerve, or at least those fibres of it which originally supplied the portions of the myomeres in question, retains its connection and is consequently drawn out far beyond its usual territory, a ready explanation being thus afforded for the extended course of the long thoracic, long subscapular, and phrenic nerves. The muscles supplied by these nerves, as well as the pectoralis major and minor muscles, are all derived from cervical myomeres, their adult position being due to the process of migration, of whose existence they form convincing examples.

6. Finally, portions of one or several successive myomeres may undergo degeneration, becoming converted into connective tissue, which may have the form of fascia, aponeurosis, or tendon. Examples of this degeneration are to be found in practically all muscles, since the tendons by which they make their bony attachments have resulted from its action. In the lower vertebrates and in the fœtus tendons and aponeuroses are much less developed than in the higher forms or in the adult, being represented by muscular tissue which later becomes converted into tendon or aponeurosis. The intermuscular septa between the muscles of the limbs seem to have arisen in this way, and occasionally relatively large aponeurotic sheets have so arisen, as in the case of the aponeurosis which unites the two posterior serratus muscles. Of especial interest in this connection are the degenerations into ligaments of muscle-tissue primarily occurring in the neighborhood of many of the joints, the accessory ligaments being in many cases formed in this manner. Thus, the external lateral ligament of the knee-joint, the ligamentum teres of the hip-joint, and even the great sacro-sciatic ligament owe their origin to this process, and many other of the ligaments may also be referred to it.

As a result of these various modifications and their combinations the individual muscles of the adult body, together with the aponeurotic sheets which are frequently associated with them, are formed.

GENERAL CONSIDERATION OF THE VOLUNTARY MUSCLES.

The voluntary or striated muscles constitute a very considerable portion of the entire mass of the body, their weight in an average adult male having been estimated at about 43.4 per cent. of the total body weight (Vierordt). Each muscle is a distinct organ composed of a number of contractile fibres united into bundles or *fasciculi* surrounded by a delicate sheath of connective tissue, the *perimysium*, in which blood-vessels and nerves ramify to the various fasciculi, and which, at the surface of the muscle, is continuous with the fascia which encloses the entire organ.

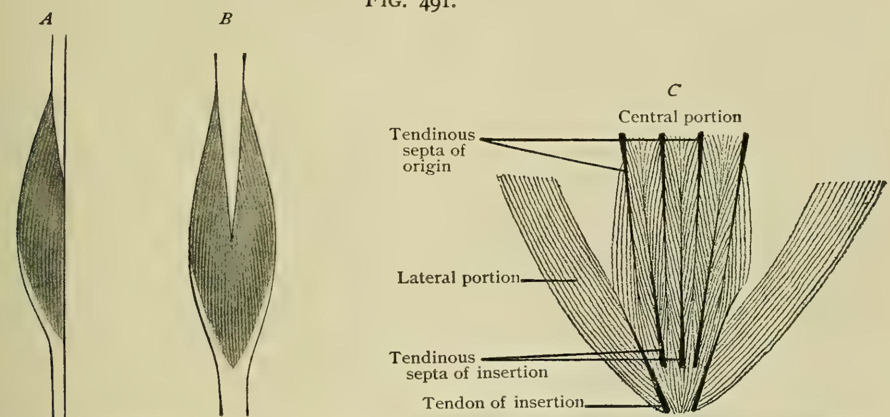
At each extremity of the muscle the contractile tissue is united with dense connective tissue, the general structure of which resembles that of the muscle, its fibres being arranged in distinct bundles separated and enclosed by looser tissue comparable to the perimysium. By means of these *tendons*, as they may generically be termed, the attachment of the muscle to portions of the skeleton or other structures is effected. The extent to which the tendon is developed varies greatly in different muscles, in some being hardly noticeable, so that the muscle-tissue appears to be directly attached to the bone (Fig. 496), at other times forming a long rounded or flattened band (Fig. 576), to which the term tendon is usually applied, or again forming a broad, flat expansion, termed an *aponeurosis* (Fig. 525). Both the tendons and aponeuroses are to be regarded as representing portions of the original muscle converted into connective tissue, and, indeed, comparative anatomy shows that many of the ligaments and aponeuroses of the body, even although they may not seem to be directly related to neighboring muscles, are really to be regarded as muscles which have undergone a tendinous degeneration.

Attachments.—The great majority of the voluntary muscles are attached at either end to portions of the skeleton, passing over one or more joints, in which they effect movement by their contraction. Occasionally, however, a muscle may be attached at one of its extremities, in part or entirely, to fascia, as, for instance, the gluteus maximus and the tensor fasciæ latæ, or both of its attachments may be to fascia, as is the case with some of the muscles of expression and with the muscles of the palate and the intrinsic musculature of the tongue. Others, again, may have their attachments to tendons of other muscles,—*e.g.*, the flexor accessorius pedis

and the lumbricales,—while others may pass between portions of the skeleton and special organs upon which they act, as is exemplified by the muscles of the eyeball.

Whatever may be the nature of the structure to which the attachment is made, it is convenient for purposes of description to regard one of the points of attachment of each muscle as the fixed point from which it acts in contraction, and to speak of this as its *origin*, and to regard the other as the point upon which it acts, speaking of it as the *insertion*. It must be understood, however, that this distinction between the two attachments is somewhat arbitrary, since what is usually the fixed point may under certain circumstances become the movable one. For instance, in the case of a muscle passing from the pelvis to a leg bone, if the body be erect, the contraction of the muscle will cause an inclination of the trunk on the hip-joint, the attachment to the leg bone being then the fixed point and that to the pelvis the movable one. In other positions of the body, however, the contraction of the muscle will produce a movement of the leg, the fixed and movable points being exactly reversed. Since, however, the movement of the leg may be regarded as the more usual result of the contraction of the muscle, the pelvic attachment is arbitrarily regarded as the origin and the attachment to the femur or tibia the insertion of the muscle in question.

FIG. 491.



Diagrams showing semi-pinnate (*A*) and pinnate (*B*) arrangement of muscle-fibres, which pass from tendon of origin above to that of insertion below. *C*, compound pinnate arrangement, as in central division of deltoid muscle. (*After Poirier.*)

Form.—The muscles assume various forms, dependent to some extent upon the structures to which they are attached. Some are thin sheets with almost parallel fibres, others are more or less band-like, while others may have considerable thickness, and be quadrate, triangular, or spindle-shaped. Surrounding certain of the orifices of the body are what are termed *orbicular* or *sphincter* muscles (Figs. 495, 499), consisting of a muscular sheet whose fibres have a crescentic course around either side of the orifice, the lips of which will tend to be drawn together by the contraction of the muscle.

Where the surfaces for attachment are considerable, the fibres composing a muscle have a more or less parallel course ; but where a comparatively small area is all that is available for the attachment of a strong muscle, as is the case with many of the limb muscles, it is clear that such an arrangement cannot obtain. The muscle-fibres then converge from either one or both sides to be inserted one above the other into the tendon, forming what is termed a *semipinnate* (e. g., many of the muscles of the leg, Fig. 609), or *pinnate* muscle (e. g., interossei dorsales, Fig. 590.) This convergence may take place towards either one or both tendons of attachment, and occasionally these may spread out over opposite surfaces of the muscle to form aponeurotic sheets which overlap, so that the muscle-fibres pass obliquely from the surface of one tendon to that of the other (*e.g.*, gastrocnemius, semitendinosus, Fig. 635). Finally, in some of the broader muscles (*e.g.*, deltoid and subscapularis) the muscle-fibres may arise from and converge to a series of tendinous bands which

alternate with one another, the muscle having thus a *compound pinnate* arrangement (Fig. 491, *C*).

As a rule, the tendons occur in connection with the extremities of the muscle, but occasionally one or more tendinous intersections may occur in the course of the muscle, which thus becomes divided into two or more bellies. This condition may be the result of the end-to-end union of the tendons of attachment of two primarily distinct muscles (*e.g.*, digastric, Fig. 497) or to the persistence of some of the dividing lines which separate the various embryonic segments of which a muscle may be composed (*e.g.*, rectus abdominis, Fig. 523); or it may be due to a secondary attachment formed by a muscle in its course, it being bound down to a neighboring bone by a band of fascia (*e.g.*, omo-hyoid).

Certain muscles present the peculiarity of possessing two or more separate heads of origin, attached to different bones and uniting to form a common tendon of insertion. In certain cases (*e.g.*, biceps femoris, pronator radii teres) this condition indicates the union of two primarily distinct muscles which had a common insertion, or which were, at all events, originally inserted close together, but in other cases it has resulted from a separation of an original muscle into two portions. The anatomical nomenclature is not quite consistent as regards such muscles, since it describes the biceps femoris as a two-headed muscle, although its two heads are fundamentally distinct organs; while, on the other hand, it usually regards the psoas and iliacus and the gastrocnemius and soleus as distinct muscles, notwithstanding their common insertion.

Fasciæ.—Connecting the various muscles and uniting them into groups, and also surrounding the entire musculature of the body and separating it from the deeper layers of the integument, are sheets of connective tissue known as *fasciæ*. These sheets are by no means isolated portions of connective tissue, but are rather to be regarded as parts of the general interstitial connective-tissue net-work which traverses all parts of the body, thickened to form more or less definite sheets standing in relation to the neighboring organs. The density of the sheets varies greatly; in some regions they are imperfectly developed and may contain considerable amounts of fat, while in others they form dense, glistening sheets resembling the expansions of tendons mentioned above, and termed, like these, *aponeuroses*.

It is convenient to recognize two principal layers of fasciæ, the superficial and the deep.

The *superficial fascia* immediately underlies the skin of the entire body, and is sometimes considered a portion of it and termed the *panniculus adiposus*, since, except in the eyelids, penis, scrotum, and labia minora, it contains considerable quantities of fat. It is connected with the subjacent deep fascia by a more or less extensively developed layer of areolar tissue, which, however, is lacking in certain regions, such, for instance, as the face, the palmar surface of the hand, and the plantar surface of the foot, where the superficial and deep fasciæ are intimately united.

The *deep fascia*, on the other hand, immediately covers and invests the muscles, and in the intervals between them becomes continuous with the periosteal connective tissue enclosing the bones. Those lamellæ of the fascia which dip down between the muscles of the limbs—the *intermuscular septa*—are frequently of considerable firmness and serve for the origin of fibres of the neighboring muscles, and occasionally muscles (*e.g.*, soleus, levator ani) take their origin in part directly from portions of the deep fascia, which then becomes thickened along the line of the origin to form strong bands, termed *arcus tendinei*, attached at either extremity to neighboring bones.

Certain portions of the deep fascia, and especially of the intermuscular septa, represent portions of the muscular system which have undergone tendinous degeneration, and are represented by muscular tissue in the lower vertebrates. Indeed, the relative amount of aponeurotic and tendinous tissue, as compared with the muscular, is very much greater in the higher than in the lower forms, and is appreciably greater in the human embryo than in the adult, indicating a transformation of one tissue into the other during the life of the individual.

Tendon-Sheaths. Where tendons run in grooves of bones, bands of dense connective tissue extend across between the lips of the grooves, being continuous

there with the periosteum, and convert the grooves into canals within which the tendons are enclosed, although capable of free movement to and fro. These connective-tissue bands are the *tendon-sheaths*, and the canals which they assist in forming may contain one or more tendons. Each sheath is lined on its deeper surface by a synovial membrane similar to those occurring in the joints, and at either extremity of the sheath this membrane is reflected upon the tendon which it encloses, so that the tendon is contained within a double-walled cylinder whose cavity is filled with a fluid serving to diminish friction during the movements of the tendon (Fig. 492). It is customary to distinguish the synovial portion of a tendon-sheath as the serous or synovial sheath (*vagina mucosa*) from the fibrous sheath (*vagina fibrosa*) with which it is always closely connected.

FIG. 492.

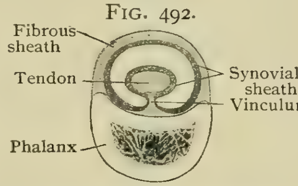


Diagram showing relations of tendon to tendon-sheath as in cross-section of finger.

Strands of connective tissue pass at intervals across the synovial cavity of the sheath from the floor of the groove on the bone and transmit blood-vessels to the tendon ; these strands constitute what are termed *vincula tendinum*, or, from their general similarity to the mesentery, *mesotendons*.

In some cases a tendon-sheath may serve to a certain extent as a pulley, affording a smooth surface over which the tendon changes its direction, as in the case of the extensor tendons of the hand when this is partly extended. A special development of this condition is to be seen in the tendinous loop (*trochlea muscularis*) over which the tendon of the superior oblique muscle of the eyeball is reflected (Fig. 516).

Bursæ.—The intervals between the various muscles and between these or their tendons and the bone are occupied by loose areolar tissue. In situations in which a muscle or tendon in its movements comes in contact with a bony prominence, or in which two tendons glide upon each other, the spaces of the areolar tissue enlarge and become filled by a fluid resembling that of the synovial cavities, the result being the formation of what is termed a *bursa*, whose purpose is to diminish the friction between the muscle or tendon and the bone. Examples of such bursæ are to be found abundantly in connection with the muscles of the limbs, and some of those which occur in the vicinity of joints frequently fuse with the adjacent synovial cavities ; the bursa of the subscapularis, situated between that muscle and the neck of the scapula, for instance, uniting with the synovial cavity of the shoulder-joint, and the bursa suprapatellaris, between the tendon of the quadriceps femoris and the femur, fusing with the cavity of the knee-joint.

Bursæ are also developed in the areolar tissue intervening between the superficial and deep fasciæ in situations in which the integument rests directly upon a bone, as, for instance, over the olecranon process, and is frequently subjected to pressure in that region. Such bursæ are termed *subcutaneous bursæ* to distinguish them from those developed in connection with the muscles.

Classification of the Muscles.—The muscles may be classified according to three plans : they may be arranged according to their topographical relations, according to their physiological significance, or, finally, upon a morphological basis, their embryological or developmental significance forming the guide for their arrangement in groups. In the following pages the last-named plan will be followed as far as possible.

Embryologically the skeletal muscles are formed, for the most part, from a series of segmentally arranged masses of mesoblast—the *mesoblastic somites*—which appear at an early stage of development on either side of the notochord and later extend ventrally towards the mid-ventral line (page 465). That portion of the musculature which has such an origin may be regarded as consisting primarily of a series of plates arranged segmentally along each side of the body, each plate corresponding to and being supplied by one of the segmental nerves and by those fibres of it which arise from the cells of the anterior horn of the spinal cord or their homologues in other portions of the central nervous system. A diagrammatic representation of this musculature in its primary condition is shown in Fig. 493, and from this it will be perceived that the series of muscle-plates extends throughout the entire trunk and neck

regions of the body and to a certain extent into the head region, there being, however, in this last region a considerable area in which the muscle-plates are unrepresented.

Throughout this area of the head region muscles occur which arise in relation to the branchial arches and, accordingly, in a much more ventral position than the mesodermic somites. Furthermore, these muscles are supplied by branches from the mixed cranial nerves, arising from cells situated in a portion of the medulla oblongata which is comparable to the lateral horn of the spinal cord and constituting what are termed lateral motor roots, in contradistinction to the median or anterior motor roots which supply the muscles derived from the mesodermic somites.

There are thus two sharply defined systems of musculature: the one, primarily confined to the cranial region, is supplied by lateral motor nerves, and from its relation to the branchial arches may be termed the *branchiomeric musculature*; the other, supplied by anterior motor nerves, is arranged primarily in a series of segmental (metameric) plates, and may be termed the *metameric musculature*. These two systems constitute the first divisions in the morphological classification of the musculature.

Fig. 493.

Diagram showing grouping of head and trunk myotomes. III, IV, VI, orbital group (supplied by cranial nerves indicated by Roman numerals) representing persisting first three cephalic myotomes; XII, hypoglossal group, representing persisting last three cephalic myotomes, intervening ones having disappeared; 1, 1, 1, 1, 1, first myotome of cervical, thoracic, lumbar, sacral, and coccygeal groups of trunk myotomes. Each myotome is divided into dorsal and ventral segments.

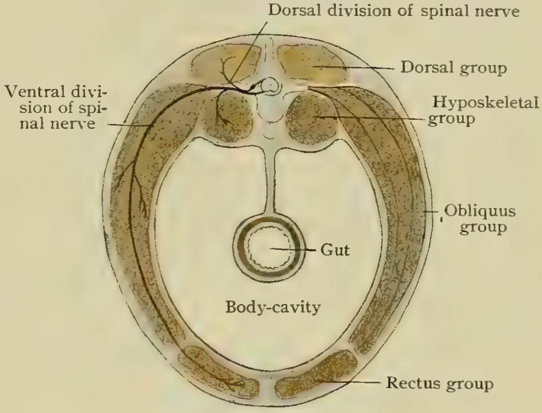
The further subdivision of the branchiomeric muscles is most conveniently made with reference to the various cranial nerves by which they are supplied. For the metameric musculature a more complicated subdivision is both necessary and convenient, and in the first place it may be divided into the *axial* and the *appendicular* musculature. For the latter group, which includes all the muscles of the limbs, a derivation from the mesodermic somites seems probable, outgrowths from certain somites extending into the limb-buds when these develop; but it has not yet been possible to demonstrate that this is the case, the limb muscles really making their appearance in an unsegmented mass of mesoblast in the limb-bud which appears to have no connection with the mesoblastic somites, these structures apparently not being continued into the limb-bud, but seeming to stop short at its base. Indeed, it is quite possible that the limb muscles should not be included under the metameric musculature; but until it is demonstrated that their mode of development is not a secondary condensation of the embryological history, it seems preferable to retain them as members of that group.

The later development of the cranial mesoblastic somites is somewhat different from that of the others, and it is consequently convenient to group the axial muscles derived from them by themselves. And since the somites form in the embryo two clearly defined groups, it seems well to place the derived muscles in two groups which may be termed respectively the *orbital* and the *hypoglossal* groups.

The remaining somites, which may be grouped together as the *trunk somites*, in their later development undergo numerous modifications, some of which may be regarded as fundamental and primarily affecting all of the series, and thus affording a basis for a further subdivision. The most fundamental of these modifications is a division of each somite into a *dorsal* and a *ventral* portion, corresponding respectively to the primary divisions of the spinal nerves, and permitting the recognition of a

dorsal and a ventral group of trunk muscles. The portions of the ventral divisions on either side of the mid-ventral line separate to form a subordinate group of muscles which may be termed the *rectus group* (Fig. 494), the more lateral portions giving rise to a group which, from the prevailing oblique course of its fibres, may be termed the *obliquus group;* and, finally, from the more dorsal portions of the ventral musculature there are developed in certain regions of the body muscles which lie ventral to the bodies or processes of the vertebræ, and may be termed the *hyposkeletal* muscles, in contrast to the remaining musculature which extends between the skeletal elements or lies dorsal to them, and hence is termed the *episkeletal* musculature.

Fig. 494.



Diagrammatic cross-section of body, showing primary groups of trunk muscles.

To sum up the classification proposed it may be represented in the following manner :

I. Branchiomeric Muscles.
II. Metameric Muscles.

A. Axial Muscles.
1. Orbital muscles.
2. Hypoglossal muscles.
3. Trunk muscles.
   a. Dorsal,
   b. Ventral.
      a. Rectus set.
      b. Obliquus set.
      c. Hyposkeletal set.

B. Appendicular Muscles.

Nerve-Supply.—The segmental regularity of the mesodermic somites is but slightly retained in the adult, numerous modifications, such as fusion, tangential and longitudinal splitting, migration, and even obliteration taking place in them to produce the various muscles of the adult. The various modifications have not in all cases been traced, but a study of the nerve-supply of a muscle gives in many, if not all, cases an important clue to its origin. This depends upon the fact that the muscles may be regarded as the end-organs of the motor nerves, and that the segmental relation established in the embryo between a nerve and the muscle-tissue derived from a given mesodermic somite is not disturbed in later development, no matter what changes of relation the muscle-tissue may undergo. Thus, when a muscle, such as the rectus abdominis, is found to be supplied by a number of spinal nerves, it is because it has been formed by the fusion of portions of a corresponding number of mesodermic somites ; and when a muscle, such as the latissimus dorsi, lying mainly in the lumbar region, is found to be supplied by a cervical nerve, it is because it has wandered from its original point of formation in the cervical region.

Variations in the nerve-supply are occasionally seen, especially in the limb muscles; but it seems probable that such variations are only apparent, the nerve-fibres supplying the muscle being in all cases strictly equivalent, arising from the same region of the spinal cord, even although they may pursue in different individuals somewhat different paths in order to reach their destination. Thus, a muscle which normally is supplied by fibres from the median nerve may sometimes be found to be

supplied by the ulnar nerve, the nerve-fibres using the ulnar nerve as a pathway by which to reach their destination, instead of the median nerve.

It is important, therefore, both from the morphological and clinical stand-points, that not only should the nerve along which the fibres pass to reach their destination be known, but also the nerve-roots by which they issue from the central nervous system.

THE BRANCHIOMERIC MUSCLES.

The branchiomeric muscles are those skeletal muscles which are derived from the mesoderm associated with the branchial arches, and are supplied by those cranial nerves whose motor fibres constitute what are termed lateral motor roots. These nerves are the trigeminus, facialis, and glossopharyngeo-vago-accessorius groups, and the classification of the muscles may well be according to their innervation by these three nerve-groups.

I. THE TRIGEMINAL MUSCLES.

The trigeminal muscles stand in relation primarily to the first embryonic or jaw-arch, and in the adult to the structures developed in association with this,—*i.e.*, to the mandible and the malleus. The *mandibular muscles* are represented by the muscles of mastication and two muscles, the mylo-hyoid and the anterior belly of the digastric, which extend between the mandible and the hyoid bone, and may be termed the *submental muscles*. Connected with the malleus is a single muscle, the tensor tympani, and an additional trigeminal muscle is found in association with the soft palate, the tensor palati.

(*a*) THE MUSCLES OF MASTICATION.

1. Masseter.	3. Pterygoideus Externus.
2. Temporalis.	4. Pterygoideus Internus.

1. Masseter (Fig. 495).

The masseter is a strong quadrilateral muscle composed of two portions, separated at their origin and posteriorly by a quantity of loose areolar tissue, but united towards their insertion into the mandible.

Attachments.—The superficial portion *arises* by a strong aponeurosis from the anterior two-thirds of the lower border of the zygoma, while the deeper part arises directly from the posterior third of the lower border and the whole of the inner surface of the zygoma. The fibres of the superficial portion pass downward and slightly backward to be *inserted* into the outer surface of the angle of the mandible, while those of the deeper portion pass more directly downward and are inserted into the outer surface of the ascending ramus as high as the bases of the articular and coronoid processes, encroaching to a certain extent upon the insertion of the temporal muscle.

Nerve-Supply.—By the masseteric branch of the anterior portion of the mandibular division of the trigeminus.

Action.—To raise the mandible and, by its superficial portion, to draw it forward to a slight extent. Owing to the fibres of the muscle being directed almost perpendicularly to the lever upon which it acts, the masseter works at much less mechanical disadvantage than is usual, and its action is therefore exceedingly powerful.

Relations.—A considerable portion of the masseter is subcutaneous. Posteriorly, however, the parotid gland rests upon its outer surface, and it is crossed by the parotid duct, the transverse facial artery, and branches of the facial nerve. Anteriorly its deep surface is separated from the buccinator muscle by a well-developed mass of fat, the buccal fat-pad (page 489).

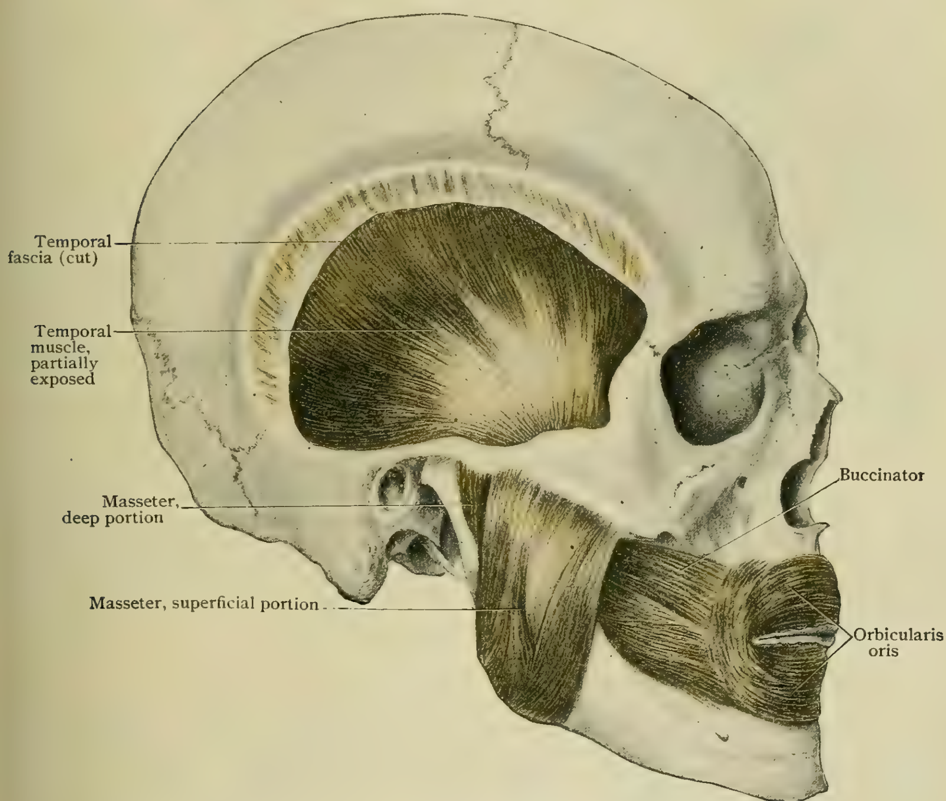
The Parotideo-Masseteric Fascia.—Covering the anterior surface of the masseter is a thin layer of fascia, the *masseteric fascia*, attached above to the zygoma

and fading out anteriorly beneath the facial muscles. Posteriorly it becomes thicker and divides into two layers to enclose the parotid gland (*parotid fascia*), the superficial layer becoming continuous behind with the layer of the deep cervical fascia which encloses the sterno-mastoid muscle, while the deeper layer is connected internally with the styloid process and joins the deep cervical fascia below. A thickening of this deeper layer forms a flat band, the *stylo-mandibular ligament*, which passes downward and outward from the styloid process to the angle of the jaw.

2. Temporalis (Fig. 495).

The *temporal fascia* forms a strong aponeurotic membrane attached above to the superior temporal line and the portion of bone between this and the inferior line, being along this attachment continuous with the periosteum. Below it divides into two layers which are separated by a quantity of adipose tissue, through which the

Fig. 495.



Lateral aspect of skull with temporal, masseter, buccinator, and oral muscles in place.

middle temporal artery may run, and is attached to the zygoma, its superficial layer inserting into the upper border of the arch and its deeper layer into the inner surface.

Attachments.—The temporal muscle *arises* from the upper half of the deep surface of the temporal fascia and from the whole extent of the floor of the temporal fossa. Its fibres converge to an exceedingly strong tendon, which *inserts* into the coronoid process of the mandible, occupying both its borders, the whole of its inner surface, and a varying amount of its outer surface.

Nerve-Supply.—By the anterior and posterior deep temporal branches from the anterior portion of the mandibular division of the trigeminus.

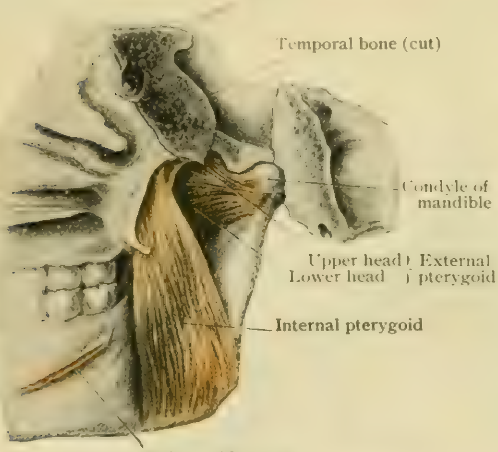
Action.—To raise the mandible. The more posterior fibres serve to retract the jaw, acting thus as an antagonist of the external pterygoid.

Relations.—Superficial to the temporal fascia are branches of the superficial temporal vessels and the auriculo-temporal nerve. Beneath, the muscle is in relation to the internal maxillary artery and the external pterygoid muscle.

3. Pterygoideus Externus (Fig. 496).

Attachments.—The external pterygoid *arises* by two heads. The upper head takes its origin from the under surface of the great wing of the sphenoid, internal to the infratemporal crest (pterygoid ridge), while the lower head arises from the outer surface of the lateral pterygoid plate. The two heads are at first separated by a narrow triangular interval through which the internal maxillary artery passes, but, passing backward and outward, they soon unite to be *inserted* into the anterior border of the interarticular fibro-cartilage of the mandibular articulation and into the neck of the condyloid process of the mandible.

Fig. 496.



External and internal pterygoid muscles, seen from within.

Nerve-Supply.—By the external pterygoid branch of the anterior portion of the mandibular division of the trigeminus.

Action.—When both muscles act together, they draw the jaw and the interarticular fibro-cartilage forward, a movement which always accompanies and assists in the depression of the jaw. When but one muscle acts, the ramus to which it is attached is drawn forward, while the other pivots in its articular surface, the result being an apparent lateral movement of the jaw towards the pivotal side.

Relations.—The outer surface of the external pterygoid is in relation to the coronoid process of the mandible and the temporal muscle, its lower head is frequently crossed by the internal maxillary artery and the buccal nerve, and anteriorly it is separated from the masseter by the buccal fat-pad. The deep surface rests upon the upper part of the internal pterygoid muscle, and is in relation to the internal maxillary artery and the inferior dental and lingual branches of the mandibular division of the trigeminus.

4. Pterygoideus Internus (Fig. 496).

Attachments.—The internal pterygoid *arises* from the walls and floor of the pterygoid fossa, the majority of its fibres being attached to the inner surface of the external pterygoid plate and to the tuberosity of the palate bone. A smaller bundle of fibres, forming what may be termed a second head, separated from the main portion of the muscle by the lower head of the external pterygoid, frequently arises from the tuberosity of the maxilla and the adjacent portion of the palate bone. From these origins the fibres are directed downward and somewhat outward and backward to be *inserted* into the inner surface of the angle and ramus of the mandible below the mylo-hyoid groove.

Nerve-Supply.—By the internal pterygoid branch from the trunk of the mandibular division of the trigeminus.

Action.—Its chief action is to raise the jaw, having in this respect almost as powerful action as the masseter. Owing to the direction of its fibres, it will also assist the external pterygoid in protruding the jaw and in producing its lateral movements.

Relations.—The outer surface of the muscle is in relation with the ramus of the mandible, the internal maxillary artery, and the inferior dental and lingual nerves

passing between the muscle and the bone. Above its larger head is covered by the external pterygoid. Its inner surface is in contact above with the tensor palati, the superior constrictor of the pharynx, and the ascending palatine artery, while towards its insertion it is in relation with the stylo-hyoid and posterior belly of the digastric and with the submaxillary gland.

Variations of the Muscles of Mastication.—The muscles of mastication are all derivatives of a single muscular mass represented by the *adductor mandibulæ* of fishes, and indications of their common origin are not infrequently to be seen in partial unions of the various muscles. Thus, fibres from the posterior portion of the deeper head of the masseter may join the temporal, fibres from both the temporal and masseter sometimes pass to the anterior border of the fibro-cartilage of the mandibular articulation, and connections have also been observed between the temporal and the external pterygoid.

Additional independent muscles apparently belonging to this group sometimes occur in the *pterygoideus proprius*, which extends from the infratemporal crest of the sphenoid to the posterior edge of the external pterygoid plate, and in the *pterygo-spinosus*, which has for its attachments the spine of the sphenoid and the posterior border of the external pterygoid plate. The significance of these muscles passing between points which are immovable is somewhat obscure. The close relationship which the pterygo-spinosus bears to the spheno-mandibular ligament seems to indicate that it represents the musculature of that portion of the mandibular arch which has become transformed into the ligament, and that usually it is represented by the connective tissue enclosing the ligament.

(*b*) THE SUBMENTAL MUSCLES.

1. Mylo-hyoideus. 2. Digastricus (Anterior Belly).

This group of trigeminal muscles contains but two representatives, the mylo-hyoid and the anterior belly of the digastric. This latter muscle, as ordinarily described, consists of two distinct muscles united at their attachment to the hyoid bone, the anterior of the two muscles belonging to the trigeminal group, while the posterior is a member of the facial group. It will be convenient to describe the muscle as a whole, even although it belongs only in part to the group under consideration.

1. Mylo-Hyoideus (Fig. 497).

Attachments.—The mylo-hyoid *arises* from practically the entire length of the mylo-hyoid ridge of the mandible, from which the fibres pass inward and slightly backward to be *inserted* for the most part into a median fibrous raphe common to the two muscles of opposite sides, the posterior fibres, however, being attached to the upper border of the body of the hyoid bone. The two muscles, taken together, form a muscular floor for the mouth, the *diaphragma oris*, upon which the tongue may be said to rest.

Nerve-Supply.—By the mylo-hyoid from the inferior dental branch of the mandibular division of the trigeminus.

Action.—To draw the hyoid bone upward and at the same time to raise the floor of the mouth, pressing the tongue against the palate.

Relations.—The superficial surface of the mylo-hyoid is in relation with the anterior belly of the digastric and with the facial artery. The submaxillary gland curves around its posterior free margin and is thus in relation with both its surfaces, the submaxillary duct running forward upon its deeper surface. This latter surface is also in relation with the genio-hyoid, genio-glossal, hyo-glossal, and stylo-glossal muscles, with the sublingual gland, and with the lingual branch of the trigeminus and the hypoglossal nerve.

2. Digastricus (Figs. 497, 502).

Attachments.—The digastric, as its name indicates, consists of two bellies which are united by a strong cylindrical tendon. The *anterior belly*, which alone belongs to the trigeminal group of muscles, *arises* from the digastric fossa of the mandible, and is directed downward, backward, and slightly outward to become con-

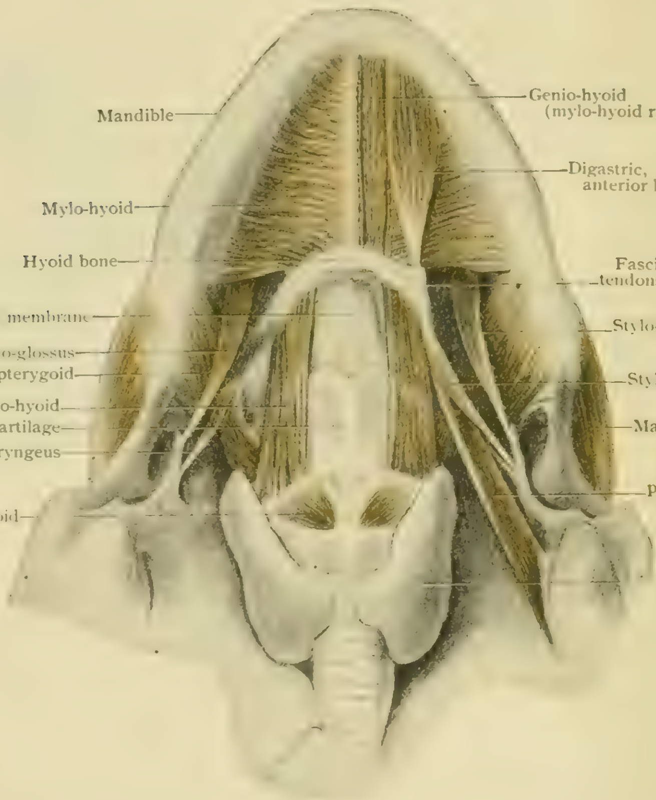
tinuous with the intermediate tendon. This is bound down to the greater horn and body of the hyoid bone by a pulley-like band of the cervical fascia and to a certain extent by the stylo-hyoid muscle, which divides near its insertion into the hyoid into two slips, between which the tendon of the digastric passes.

The *posterior belly* (Fig. 502) takes its *origin* from the mastoid groove of the temporal bone, and passes downward and forward to become connected with the intermediate tendon.

Nerve-Supply.—The anterior belly is supplied by the mylo-hyoid nerve from the inferior dental branch of the mandibular division of the trigeminus, the posterior belly by the digastric branch of the facial.

Action.—The digastric either raises the hyoid bone or depresses the jaw,

FIG. 497.



Submental muscles from below; trachea has been displaced downward and backward.

according as one or other of the bones is fixed by the antagonizing muscles. By raising the hyoid when the mandible is fixed, it assists the mylo-hyoid in pressing the tongue against the palate during the first portion of the act of deglutition, and in the second portion of that act the posterior belly will assist the stylo-hyoid in drawing the hyoid upward and backward and so help in elevating the larynx.

Relations.—The anterior belly rests upon the mylo-hyoid muscle. The posterior belly is covered by the sterno-mastoid and splenius muscles, and crosses both the external and internal carotid arteries, the internal jugular vein, and the pneumogastric and spinal accessory nerves.

Variations.—A close relationship exists between the mylo-hyoid and the anterior belly of the digastric, and there is usually more or less exchange of fibres between the two muscles, sometimes amounting to a complete fusion. A duplicity of the anterior belly is a rather fre-

quent variation, and the anterior bellies of opposite sides may be united by the more or less complete conversion of the fascia which typically passes between them into muscular tissue. An independent muscle extending between the body of the hyoid and the symphysis of the mandible, and termed the *mento-hyoid*, occasionally is found running alongside of the medial border of the anterior belly, and is to be regarded as a separated portion of that muscle.

As regards the posterior belly, it may take its origin from any part of the mastoid groove or even from the outer portion of the superior nuchal line, and occasionally it fuses completely with the stylo-hyoid. In certain cases in which there is a failure of the anterior belly to differentiate from the mylo-hyoid, the posterior belly is inserted into the angle of the mandible instead of into the hyoid bone,—a condition recalling the arrangement typical in the majority of the mammalia, in which the posterior belly of the digastric is represented by a *depressor mandibulæ.*

(*c*) THE TRIGEMINAL PALATAL MUSCLE.

1. Tensor Palati (Fig. 509).

Attachments.—The tensor palati (tensor veli palatini) takes its *origin* from the scaphoid fossa and spine of the sphenoid and from the outer surface of the cartilaginous portion of the Eustachian tube. It descends along the outer surface of the internal pterygoid plate, and, becoming tendinous, bends at right angles around the hamulus and is continued inward to be *inserted* into the posterior border of the palate bone and into the aponeurosis of the soft palate.

Nerve-Supply.—By fibres from the mandibular division of the trigeminus, which traverse the otic ganglion.

Action.—It tends to draw the soft palate to one side. The two muscles acting together will stretch the soft palate.

(*d*) THE TRIGEMINAL TYMPANIC MUSCLE.

1. Tensor Tympani (Fig. 1252).

Attachments.—The tensor tympani is a small bipenniform muscle which lies in a bony canal situated above the Eustachian tube. Its fibres take their *origin* from the cartilaginous portion of the Eustachian tube, the adjacent portions of the great wing of the sphenoid, and also to a certain extent from the walls of the bony canal. The tympanic end of the Eustachian tube is separated from the opening of the canal for the tensor by a bony ridge, the processus cochleariformis, over which the tendon of the tensor bends almost at right angles and passes outward across the tympanic cavity to be *inserted* into the manubrium mallei near its attachment to the head of the bone.

Nerve-Supply.—By fibres from the mandibular division of the trigeminus, which traverse the otic ganglion.

Action.—The muscle draws the handle of the malleus inward and so tenses the membrana tympani.

II. THE FACIAL MUSCLES.

The muscles supplied by the facial nerve are readily divisible into two groups. Primarily this musculature is associated with the second branchial or hyoid arch, represented in the adult by the lesser cornu of the hyoid bone, the stylo-hyoid ligament, styloid process, and stapes, and a small group of muscles—the stylo-hyoid, the posterior belly of the digastric, and the stapedius—are still found in relation to these structures. From the surface of the mass from which these muscles differentiate there is separated at an early stage a layer which gradually increases in extent and eventually covers all the neck and head in a cowl, as it were, its progress from the hyoid arch being followed by a branch of the facial nerve, which eventually, with the growth of the muscle, increases to such an extent as to appear to be the main stem of the nerve. From the muscular sheet numerous superficial muscles of the head and neck develop, and the entire group so formed may be termed, from one of its principal members, the platysma group, the group retaining the primary relationships forming the hyoidean group.

(*a*) THE HYOIDEAN MUSCLES.

1. Stylo-hyoideus. 2. Digastricus (Posterior Belly). 3. Stapedius.

1. Stylo-Hyoideus (Figs. 497, 502).

Attachments.—The stylo-hyoid forms a slender spindle-shaped muscle which *arises* from the upper portion of the styloid process and passes obliquely downward and forward to be inserted into the base of the greater cornu of the hyoid bone, usually dividing before its *insertion* into two slips, between which the intermediate tendon of the digastric passes.

Nerve-Supply.—By a branch from the digastric branch of the facial nerve.

Action.—To raise and draw backward the hyoid bone.

Relations.—Above the stylo-hyoid descends along the inner border of the posterior belly of the digastric, passing in front of that muscle below. Internal to it is the stylo-pharyngeus, and below the hyo-glossus and the glosso-pharyngeal and hypoglossal nerves, passing forward between it and the stylo-pharyngeus.

2. Digastricus (Posterior Belly). See page 478.

3. Stapedius (Fig. 1254).

Attachments.—The stapedius *arises* from the walls of the cavity contained within the pyramidal eminence, and its tendon, entering the tympanic cavity through the aperture at the apex of the eminence, is *inserted* into the neck of the stapes.

Nerve-Supply.—By a small branch arising from the facial nerve during its course through the lower part of the facial (Fallopian) canal.

Action.—By its contraction it draws the head of the stapes towards the posterior wall of the tympanic cavity, depressing the posterior part of the foot-plate of the bone while it raises the anterior part, thus tensing the membrane which closes the fenestra ovalis.

Variations of the Hyoidean Muscles.—A close relationship exists between the stylo-hyoid and the posterior belly of the digastric, the one or the other occasionally failing to separate from the common mass from which they are derived. A bundle of muscle-fibres sometimes passes from the tip of the styloid process to the angle of the mandible, forming what may be termed the *stylo-mandibularis*, and recalling by its insertion the condition presented in certain cases by the posterior belly of the digastric (page 479).

A duplication of the stylo-hyoid has also been observed, the second slip, which has been termed the *stylo-hyoideus profundus*, varying considerably in its insertion, sometimes accompanying the stylo-hyoid proper and sometimes inserting into the lesser cornu of the hyoid, and in some cases replacing the stylo-hyoid ligament.

The division of the stylo-hyoid near its insertion for the passage of the intermediate tendon of the digastric does not always occur, the insertion being by a single head which may pass either to the outer or the inner side of the tendon.

(*b*) THE PLATYSMA MUSCLES.

(*a*) Superficial Layer.

1. Platysma.
2. Occipito-frontalis.
3. Auricularis posterior.
4. Auricularis superior.
5. Auricularis anterior.
6. Orbicularis palpebrarum.
7. Zygomaticus major.
8. Levator labii superioris alæque nasi.
9. Depressor labii inferioris.
10. Levator menti.

(*b*) Deep Layer.

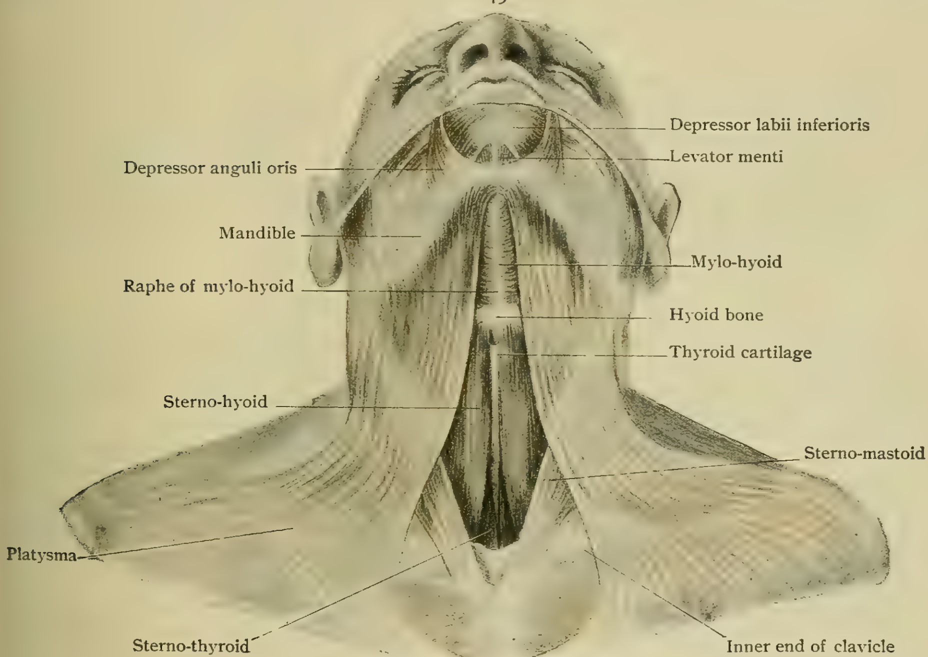
1. Orbicularis oris.
2. Nasalis (compressor nasi et depressor alæ nasi).
3. Levator labii superioris.
4. Levator anguli oris.
5. Risorius.
6. Depressor anguli oris.
7. Buccinator.

The comparative and embryological study of the platysma muscles have shown their origin from the musculature of the second or hyoid arch and their extension

thence over the head and neck. At first they are confined entirely to the neck region, but even in the lower mammals the extension upon the head has begun, and in the higher members of this group two portions can be distinguished in the muscle-sheet. The more superficial of these is situated in the lateral and posterior portions of the neck, and extends thence upon the sides of the face and over the vertex of the skull to the orbital and nasal regions of the face. The deeper one lies more anteriorly in the neck, and extends upward over the jaw to the region around the mouth.

In the higher forms a differentiation of both layers to form a number of more or less separate muscles takes place and reaches its highest development in man, whose mobility of facial expression is due to the existence of a considerable number of platysma muscles. These muscles have arisen from the common sheets by the partial conversion of these into connective tissue, by the secondary attachment of portions of the sheets to the skeleton, by various modifications of the primary direction of the fibres, and by the obliteration of certain portions of the sheet found in the

FIG. 498.



Superficial muscles of neck.

lower animals, the cervical portion of the deep layer, for instance, being normally lacking in man, the layer being represented only by the muscles of the lips.

The platysma musculature is characterized for the most part by the pale color of its fibres, by their aggregation to form thin bands or sheets usually more or less intermingled with connective-tissue strands, so that their margins are, as a rule, ill-defined, and by their attachment in frequent cases to the integument. These peculiarities, together with a considerable amount of variation which occurs in the differentiation of the various muscles, have brought about not a little difference in the number of muscles recognized in the group by various authorities, some recognizing as distinct muscles what others regard as merely more or less aberrant or unusually developed slips.

(*a*) THE MUSCLES OF THE SUPERFICIAL LAYER.

1. PLATYSMA (Figs. 498, 499).

Attachments.—The platysma takes its *origin* from the skin and subcutaneous tissue over the pectoralis major and deltoid muscles on a line extending from the cartilage of the second rib to the tip of the acromion process. Its fibres are directed

upward and inward and are *inserted* into the body of the mandible from the symphysis to the insertion of the masseter, the more posterior fibres extending upward upon the face towards the angle of the mouth and becoming lost partly in the fascia of the cheeks and partly among the muscles of the lips.

Nerve-Supply.—By the inframandibular branch of the facial nerve.

Action.—The contraction of the platysma results in drawing the lower lip downward and outward and at the same time raising the skin of the neck from the underlying parts. It is one of the most important muscles employed in the expression of horror and intense surprise. It does not seem probable that the muscle has much effect in producing depression of the mandible, an action which it might be expected to possess on account of its upper attachment.

Relations.—The platysma rests upon the deep fascia of the neck and covers all the structures at the front and sides of that region. Upon its deep surface lie the external jugular vein, the superficial lymph-nodes of the neck, and the superficial branches of the cervical plexus. It covers also the sterno-mastoid muscle and the depressors of the hyoid bone, and, above, the digastric and mylo-hyoid muscles, together with the submaxillary gland and the lower portion of the parotid.

Variations.—There is usually more or less decussation of the two muscles across the median line, especially in their upper parts, where, indeed, a certain amount of decussation may be considered a normal condition. The muscle is subject to considerable amounts of variation in its development, sometimes forming a very thin, pale layer largely interspersed with connective tissue, and at other times it is composed of strong, deeply colored bundles with much less intermixture of connective tissue. Its extension upon the face may also vary considerably, sometimes being traceable as high up as the zygoma and extending backward to behind the ear. On the other hand, it may be very considerably reduced in size, especially below, a complete absence of the lower half of the muscle having been observed.

2. Occipito-Frontalis (Fig. 499).

Attachments.—The occipito-frontalis (**m. epicranius**) is a muscular and aponeurotic sheet which covers the entire vertex of the skull from the occipital region to the root of the nose. It consists of two muscular portions, one of which, the *occipitalis*, *arises* from the superior nuchal line and *inserts* after a short course into the posterior border of the epicranial aponeurosis, while the other, the *frontalis*, taking its *origin* from the anterior border of the galea, is *inserted* into the skin in the neighborhood of the eyebrows, over the glabella, and into the superciliary arches, a portion of it being frequently prolonged downward upon the nasal bone, forming what has been termed the *pyramidalis nasi* (**m. procerus**), which is frequently described as a distinct muscle.

The *epicranial aponeurosis* (**galea aponeurotica**) (Fig. 499) is a dense aponeurotic sheet which covers the entire vertex of the cranium and is prolonged laterally over the temporal fascia as a thin layer which extends almost to the zygoma. On its superficial surface it is intimately associated with the integument, being united to its deeper surface by a thin but close and resistant layer of fascia which represents the superficial fascia of other regions of the body and in which are embedded the vessels and nerves of the scalp. The under surface of the galea is, however, smooth, and is connected with the periosteum by a lax layer of connective tissue, so that it is capable of considerable movement to and fro upon the periosteum, the skin being carried with it in such movements. A section through the scalp at the vertex would show from without inward (1) the skin, (2) the dense superficial fascia with its vessels and nerves, (3) the epicranial aponeurosis, (4) loose connective tissue, and (5) periosteum (Fig. 504).

Nerve-Supply.—The occipitalis is supplied by branches from the posterior auricular branch of the facial, the frontalis by branches from the rami temporales of the same nerve.

Action.—The occipitalis acting alone will draw backward the galea aponeurotica, while the frontalis draws it forward. If, however, the galea be fixed by the occipitales, the action of the frontales is to raise the eyebrows and throw the skin of the forehead into transverse wrinkles, both of these actions being greatly increased by the simultaneous contraction of both the occipitales and the frontales. It is consequently the

muscle employed in the expression of interrogation and surprise and also, in conjunction with the platysma, in that of horror.

The ***transversus nuchæ*** is a thin muscular band, frequently present, arising from the occipital protuberance and extending laterally to terminate in various attachments; sometimes, for instance, uniting with the posterior border of the sterno-cleido-mastoid or with the auricularis posterior. It may take its origin either superficial to or beneath the attachment of the trapezius to the superior nuchal line, and in the former case is to be regarded as a portion of the platysma group of muscles, while in the latter it is more probably a relic of the primary connection between the trapezius and the sterno-cleido-mastoid and belongs to that group of muscles (page 501).

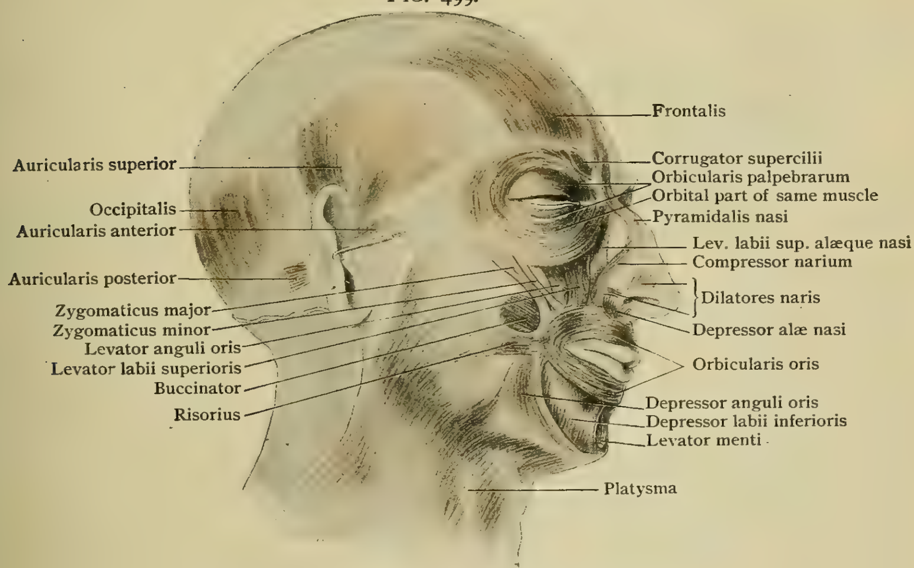
3. Auricularis Posterior (Fig. 499).

Attachments.—The posterior auricular (*retrahens aurem*) is composed of a few bundles of fibres which *arise* from the outer extremity of the superior nuchal line and the base of the mastoid process and pass horizontally forward to be *inserted* into the posterior surface of the concha. It is frequently imperfectly separated from the occipitalis.

Nerve-Supply.—By the posterior auricular branch of the facial nerve.

Action.—To draw the auricle backward.

Fig. 499.



Superficial dissection of head, showing platysma muscles.

4. Auricularis Superior (Fig. 499).

Attachments.—The superior auricular (*attollens aurem*) is a triangular muscle which *arises* from the lateral portion of the galea aponeurotica or from the temporal fascia and converges to be *inserted* into the upper part of the cartilage of the auricle.

Nerve-Supply.—By fibres from the rami temporales of the facial nerve.

Action.—To draw the auricle upward.

5. Auricularis Anterior (Fig. 499).

Attachments.—The anterior auricular (*attrahens aurem*) is frequently continuous with the preceding muscle, lying immediately anterior to it. It *arises* from the lateral part of the galea aponeurotica or from the temporal fascia and is *inserted* into the upper anterior part of the auricular cartilage or into the fascia immediately anterior to the cartilage.

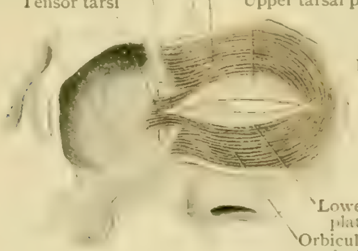
Nerve-Supply.—By fibres from the rami temporales of the facial nerve.
Action.—To draw the auricle upward and forward.

6. Orbicularis Palpebrarum (Figs. 499, 500).

The orbicularis palpebrarum (**m. orbicularis oculi**) is an elliptical sheet whose fibres have their *origin* in the neighborhood of the inner angle of the eye and curve thence, some upward and outward and some downward and outward, around the rima palpebralis to terminate in the neighborhood of the external angle. The course of the fibres lies partly in the substance of the upper and lower eyelids and partly over the bones surrounding the margin of the orbit. In accordance with these relations, it is customary to regard the muscle as consisting of two main portions, the *pars palpebralis* and the *pars orbitalis*.

The *internal palpebral ligament* (**ligamentum palpebrale mediale**). Where the fibres of the orbicularis arise at the inner angle of the eye there is a dense band of fibrous tissue which is attached at one extremity to the frontal process of the maxilla. Thence it is directed outward across the outer surface of the lachrymal sac and bifurcates to be inserted into the inner border of each tarsal plate. Just before its bifurcation the ligament gives off from its posterior surface a bundle which is reflected inward over the lachrymal sac and passes behind this to be attached to the crest of the lachrymal bone.

Fig. 500.



Orbicularis palpebrarum has been dissected from its deeper surface and reflected inward with eyelids, showing lachrymal portion or tensor tarsi.

This ligament, which is also known as the *tendo oculi*, may be regarded as the tendon of origin of the fibres of the orbicularis oculi. At the outer angle of the eye there is a certain amount of decussation of the fibres of the muscle to form a *raphe palpebralis lateralis*, but there is no distinct formation of a fibrous band comparable to the internal ligament.

Pars Palpebralis.—The palpebral portion of the muscle *arises* partly from the internal palpebral ligament and partly from the crest of the lachrymal bone. The fibres which take origin from the ligament arch outward in the upper and lower eyelids to terminate in the lateral palpebral raphe, forming a thin, pale sheet in the subcutaneous tissue of the eyelid. Its marginal fibres, sometimes more or less distinct from the others, form what has been termed the *pars ciliaris* or *muscle of Riolan*.

The fibres which arise from the posterior lachrymal crest are usually regarded as forming either a distinct muscle, which has been termed the *tensor tarsi* or *Horner's muscle*, or else as a separate part of the orbicularis, the *pars lacrimalis*. It is directed horizontally outward behind the lachrymal sac, resting upon the posterior surface of the reflected bundle of the internal palpebral ligament. Towards its outer end it bifurcates, sending a slip to each eyelid partly to be *inserted* into the tarsal plates and partly to fuse with the rest of the pars palpebralis.

Pars Orbitalis.—The orbital portion of the muscle is usually of a deeper color and somewhat thicker than the palpebral, and the fibres towards its periphery tend to scatter themselves among the adjacent platysma muscles and to make numerous connections with these. Some bundles from the lateral and lower parts of the muscle which extend downward and forward upon the cheek have been regarded as a distinct muscle, the *malaris*.

The main muscle *arises* from the internal palpebral ligament, the frontal process of the maxilla, and the inner portions of the upper and lower margins of the orbit. The fibres arch outward to the lateral palpebral raphe, a portion of those arising from the maxilla *inserting* into the integument of the eyebrow and forming what has been termed the *corrugator supercilii* (Fig. 499).

Nerve-Supply.—By the rami temporales and zygomatici of the facial nerve.

Action.—The principal action of the orbicularis palpebrarum is to approximate the upper and lower eyelids, closing the palpebral fissure. In addition, the attachment of the orbital portion to the skin draws the eyebrow downward and the skin of the cheek upward to form a fold around the margin of the orbit, giving increased protection to the eyeball. The corrugator supercilii draws the eyebrow downward and inward, producing vertical wrinkles of the integument over the glabella and giving a thoughtful expression.

The pars lacrimalis draws the tarsal plates inward and backward and so tenses the internal palpebral ligament, causing it to compress the lachrymal sac.

7. Zygomaticus Major (Figs. 499, 502).

Attachments.—The zygomaticus major (**m. zygomaticus**) is a slender muscle which *arises* above from the outer surface of the zygomatic bone, near its articulation with the zygomatic process of the temporal, and passes obliquely downward and forward towards the angle of the mouth. Its fibres interlace with those of the depressor and levator anguli oris, and terminate by blending with the orbicularis oris and by *inserting* into the subcutaneous tissue of the lips.

Nerve-Supply.—By fibres from the zygomatic branch of the facial nerve.

Action.—To draw upward and outward the angles of the mouth, as in smiling and laughing.

Variations.—A slender muscle is very frequently found arising from the zygomatic bone anterior to the zygomaticus and passing downward to be inserted into the upper lip. It has been termed the *zygomaticus minor*, and appears to be a separation of a portion of the zygomatic muscle.

8. Levator Labii Superioris Alæque Nasi (Figs. 499, 501).

Attachments.—This muscle takes its *origin* from the outer surface of the frontal process of the maxilla, and descends along the angle which marks the junction of the nose and the cheek to be *inserted* into the integument of the upper lip and into the posterior part of the ala nasi.

Nerve-Supply.—From the rami zygomatici of the facial nerve.

Action.—The principal action of this muscle is to raise the upper lip, although its insertion into the ala nasi enables it to assist in the dilatation of the nostrils.

Variations.—This muscle is subject to considerable variation in its development, and frequently comes into continuity with neighboring muscles, especially with the zygomaticus minor, when this is present, and with the levator labii superioris proprius. Indeed, these two muscles are often associated with it to form what is termed the *quadratus labii superioris*, of which the levator labii superioris alæque nasi forms the *caput angulare*, the levator labii superioris proprius the *caput infraorbitale*, and the zygomaticus minor the *caput zygomaticus*. Since, however, the levator labii superioris proprius belongs to the deep layer of the platysma muscles, and therefore to a different group than the other heads of the quadratus, it seems preferable to regard all the heads as distinct muscles.

9. Depressor Labii Inferioris (Figs. 498, 499).

Attachments.—The depressor of the lower lips (**m. quadratus labii inferioris**) *arises* from the body of the mandible beneath the canine and premolar teeth, its origin being covered by the depressor anguli oris. It forms a thin quadrate sheet which is directed upward and forward and is *inserted* in the skin of the lower lip, its fibres mingling also with those of the orbicularis oris.

Nerve-Supply.—From the supramandibular branch of the facial nerve.

Action.—To draw down the lower lip.

10. Levator Menti (Fig. 498).

Attachments.—The levator menti (**m. mentalis**) *arises* from the body of the mandible below the incisor teeth, and its fibres descend, diverging as they go, to be *inserted* into the integument above the point of the chin.

Nerve-Supply.—From the supramandibular branch of the facial nerve.

Action.—To draw upward the skin of the chin, thereby causing protrusion of the lower lip, as in pouting. When its action is combined with contraction of the depressors of the angles of the mouth, it gives an expression of haughtiness or contempt, and has thence been termed the *m. superbus*. When slightly contracted, it gives an expression of firmness or decision.

Belonging to the superficial layer of the platysma musculature are a number of additional more or less rudimentary muscles attached at both extremities to various parts of the cartilage of the concha. These muscles will be considered in connection with the description of the ear (page 1499).

(*b*) THE MUSCLES OF THE DEEP LAYER.

1. Orbicularis Oris (Figs. 499, 501, 503).

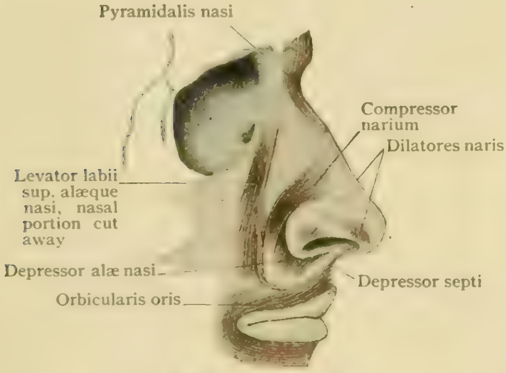
Attachments.—The orbicularis oris is a rather strong elliptical muscle whose fibres occupy the thickness of both the upper and lower lips between the skin and the mucous membrane of the mouth. For the most part the fibres composing the muscle are forward prolongations of the buccinator, but mingled with these there are fibres from all the muscles which are inserted in the vicinity of the mouth, such as the zygomaticus, levator anguli oris, levator labii superioris, depressor anguli oris, depressor labii inferioris, and risorius.

It possesses, however, some slight attachment to skeletal structures by three groups of fibres which have frequently been regarded as distinct muscles. These groups are: (1) the *incisivi labii superioris*, a series of bundles of fibres which arise from the incisive fossæ of the maxillæ and pass downward and outward to mingle with the other fibres of the orbicularis at the angles of the mouth; (2) the *incisivi labii inferioris*, which arise from the alveolar border of the mandible beneath the canine teeth and unite with the orbicularis at the angles of the mouth; and (3) the *depressor septi*, composed of the uppermost fibres of the orbicularis, which bend upward from either side in the median line and are inserted into the margin of the septal cartilage of the nose.

Nerve-Supply.—From the rami buccales and supramandibular branch of the facial nerve.

Action.—The main action of the orbicularis oris is to bring the lips together, closing the mouth, and if its action be continued, it will press the lips against the teeth. Its more peripheral fibres, aided by the incisive bundles, will tend to protrude the lips.

Fig. 501.



Muscles of the nose.

2. Nasalis (Fig. 501).

Attachments.—The nasalis forms a thin sheet which *arises* from the maxilla in close association with the incisive bundles of the upper lip. The more medial fibres, the **pars alaris** (*depressor alæ nasi*), are *inserted* into the alar cartilage of the nose, while the more lateral ones, the **pars transversa** (*compressor narium*), often receiving slips from the adjacent levator labii superioris alæque nasi and the levator anguli oris, extend forward over the ala of the nose to terminate upon its dorsal surface in a thin aponeurosis which unites it to the muscle of the opposite side.

Nerve-Supply.—From the zygomatic and buccal rami of the facial nerve.

Action.—The more median fibres draw the alar cartilage downward and inward, while the more lateral ones slightly depress the tip of the nose and at the same time compress the nostril.

Variations.—Fibres from the nasalis sometimes pass upward upon the nasal bones and may enter into the formation of the *pyramidalis nasi* (page 482). Frequently the pars alaris and pars transversa are recognized as distinct muscles, the former being termed the *depressor alæ nasi* or *myrtiformis*, while the latter is named the *compressor narium*. Uncertain and at best feeble muscular slips on the outer margin of the nostrils are sometimes described as distinct muscles, the *dilatores naris anterior et posterior*.

3. Levator Labii Superioris (Fig. 499).

Attachments.—The elevator of the upper lip (**m. levator labii superioris proprius**) *arises* above from the infraorbital margin of the maxilla and extends almost vertically downward over the infraorbital vessels and nerve to join with the orbicularis oris and also to be *inserted* into the skin of the upper lip between the insertions of the levator labii superioris alæque nasi and the levator anguli oris.

Nerve-Supply.—From the zygomatic branches of the facial nerve.

Action.—To raise the upper lip. Acting in conjunction with the levator labii superioris alæque nasi, it plays an important part in the expression of grief.

4. Levator Anguli Oris (Figs. 499, 502).

Attachments.—The elevator of the angle of the mouth (**m. caninus**) *arises* from the canine fossa of the maxilla by a rather broad origin, from which its fibres converge to be *inserted* into the skin at the angle of the mouth, partly mingling with the fibres of the depressor anguli oris.

Nerve-Supply.—From the zygomatic branches of the facial nerve.

Action.—To raise the angle of the mouth.

5. Risorius (Fig. 499).

Attachments.—The risorius is a triangular sheet of muscle which *arises* from the outer surface of the parotido-masseteric fascia and from the integument of the cheek and passes forward towards the angle of the mouth, where it unites with the depressor anguli and orbicularis oris.

Nerve-Supply.—From the rami buccales of the facial nerve.

Action.—To draw the angle of the mouth outward. Its contraction imparts a tense and strained expression to the face which is termed the risus sardonicus.

Variation.—The risorius is frequently absent, and may be represented only by some scattered muscular bands. Its intimate association with the depressor anguli oris indicates its derivation from that muscle.

6. Depressor Anguli Oris (Figs. 498, 499).

Attachments.—The depressor of the angle of the mouth (**m. triangularis**) takes its *origin* from the outer surface of the body of the mandible and from the skin and passes upward to the angle of the mouth, where its fibres are *inserted* into the skin and also mingle with those of the caninus, risorius, and orbicularis oris.

Nerve-Supply.—From the supramarginal branch of the facial nerve.

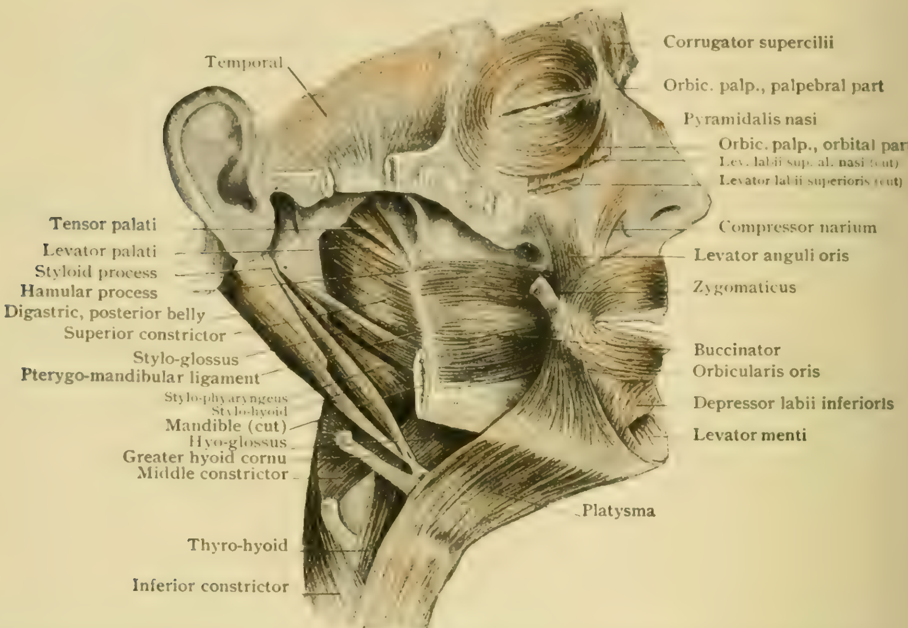
Action.—To draw the angle of the mouth downward and slightly outward, giving an expression of sorrow.

Variations.—A bundle of fibres not infrequently arises from the anterior border of the depressor anguli oris near its origin and passes obliquely downward and inward towards the median line beneath the chin, either losing itself in the superficial fascia of that region or uniting with its fellow of the opposite side. This slip has been regarded as a distinct muscle and termed the *transversus menti*. It seems exceedingly probable that both this bundle and the risorius are derivatives of the depressor, and this muscle, notwithstanding its position superficial to both the depressor labii inferioris and the platysma, is really a portion of the deeper layer of the platysma musculature, its present position having been acquired by a migration from the region of the upper lip.

7. Buccinator (Fig. 502).

Bucco-Pharyngeal Fascia.—The buccinator alone of the platysma group of muscles is covered by a distinct layer of fascia which forms the anterior part of the **fascia buccopharyngea** and is a dense, resistant sheet of connective tissue intimately

Fig. 502.



Oral, pharyngeal, and styloid groups of muscles; part of mandible has been removed to show deeper structures.

adherent to the outer surface of the muscle. Anteriorly the fascia thins out to disappear in the tissue of the lips; above it is attached to the alveolar portion of the maxilla and to the internal pterygoid plate of the sphenoid, and thence is continued backward over the superior constrictor muscle of the pharynx to meet with its fellow of the opposite side behind the pharynx; below it is attached to the posterior part of the mylo-hyoid ridge of the mandible. Along a line which descends vertically from the tip of the hamulus of the sphenoid to the posterior extremity of the mylo-hyoid ridge of the mandible the fascia is greatly thickened, forming the *pterygo-mandibular ligament*, from which fibres of the buccinator arise anteriorly, while posteriorly it gives origin to a portion of the superior constrictor of the pharynx.

Fig. 503.

Diagram showing course of component fibres forming orbicularis oris muscle.

Attachments.—The buccinator forms a thick quadrilateral muscle lying immediately exterior to the mucous membrane of the cheek. Its line of *origin* is horseshoe-shaped, extending above along the alveolar border and tuberosity of the maxilla and thence upon the hamulus

of the internal pterygoid plate of the sphenoid. It then descends upon the anterior border of the pterygo-mandibular raphe, whence it passes forward along the body of the mandible, above the mylo-hyoid ridge, as far as the premolar teeth. From this extensive origin its fibres are directed forward to become continuous with those of the orbicularis oris, also *inserting* to a certain extent into the integument of the lips.

Nerve-Supply.—From the buccal branch of the facial nerve.

Action.—The buccinator draws the angle of the mouth laterally, pressing the lips against the teeth. When the cheeks are distended the muscle serves to compress the contents of the mouth, and plays an important part in mastication in preventing the accumulation of the food between the cheek and the jaws, forcing it back between the teeth.

Relations.—Superficially with the bucco-pharyngeal fascia, which is separated from the anterior part of the masseter and from the zygomaticus and risorius by an extensive pad of fat,—the *buccal fat-pad*. This is prolonged backward into the zygomatic fossa between the temporal and pterygoid muscles, and is traversed by the facial vessels and the buccal branches of the trigeminal and facial nerves.

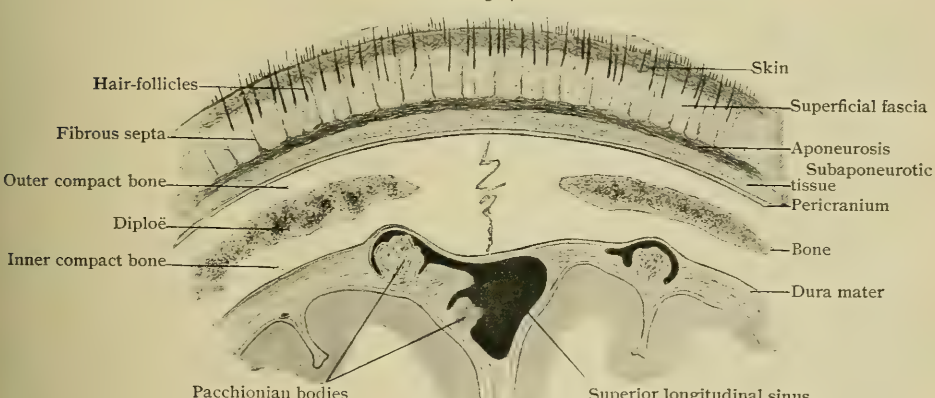
The buccinator is pierced from without inward by the parotid duct and by the buccal branch of the trigeminal nerve on its way towards its distribution to the mucous membrane of the cheek.

PRACTICAL CONSIDERATIONS: MUSCLES AND FASCIÆ OF THE CRANIUM.

The Scalp.—*The Occipito-Frontal Region.*—The layers of the scalp from within outward are:

1. The *pericranium*—as the periosteum covering this part of the skull is termed—closely invests the underlying bones and is firmly attached at the sutures through which, so long as these remain ununited, it is continuous (intersutural membrane) with the outer layer of the dura,—the endosteum of the cranium. A similar

FIG. 504.



Portion of frontal section of head hardened in formalin, showing layers of scalp, skull, and meninges. × 2½.

and more constant continuity exists through the foramina. As the dura is the chief source of blood-supply of the cranial bones, they rarely necrose after accidents which strip the pericranium from their surface (page 237). Subpericranial effusions of blood, or collections of pus, are limited and outlined by the lines of the sutures. "Cephalhæmatomata" in this situation correspond in shape to that of one bone; they are commonly congenital, constituting a form of caput succedaneum, following head presentations, and are then apt to be found over a parietal bone, since that region is most exposed to pressure during child-birth. Tillaux suggests that in early life they may be encouraged by the softness and vascularity of the cranial bones and the

laxity of the pericranium, and that their greater frequency in male children may depend upon the larger size of the head in the male fœtus. The close association of the bloody effusion with the pericranium—an osteogenetic membrane—sometimes results in the development of bone at the periphery of the swelling. The hard ridge which is usually present at this situation may give rise, through contrast with the relatively depressed centre, to the mistaken diagnosis of fracture of the skull.

Occasionally a collection of blood beneath the pericranium communicates with the diploic sinuses, when it will probably be situated to one side of the cranium ; or with the superior longitudinal sinus, when it will be in the mid-line. No traumatic history may be obtainable. The swelling will be soft, reducible, of varying tension, and may receive from the brain a feeble pulsatile impulse.

The importance of the emissary veins in transmitting extracranial infection to the venous channels of the dura may be mentioned here, but can better be understood after the venous system has been described (page 876).

2. The *subaponeurotic connective tissue* between the pericranium and the aponeurosis of the occipito-frontalis. This is so loose, thin, and elastic that the union between these layers is not a close one. The motion of the "scalp" upon the skull is a motion of the parts above upon the parts beneath this layer. Movable growths will, therefore, be found to occupy the former region and immovable swellings will probably have deeper attachments. Effusions of blood, suppuration, or infective cellulitis occurring in the subaponeurotic space may extend widely, and may be limited only by the attachments of the musculo-fibrous layer. They may reach, therefore, posteriorly to the superior curved line of the occipital bone, anteriorly to a little above the eyebrows, and laterally to a level somewhat above the zygoma. Extensive hæmatomata are uncommon, as the vessels in this cellular tissue are few and small. If they are large, they suggest fracture of the skull with laceration of a branch of the middle meningeal artery or of a venous sinus. They may, however, by reason of a hard border and soft centre, be mistaken for depressed fracture when the skull itself is uninjured.

Suppuration and cellulitis are often serious on account of the tendency to spread, the possible extension to the meninges, and the difficulty in applying antisepsis, in securing drainage, or, later, in obtaining the rest necessary for rapid healing. In abscess the diffusion of the pus is favored by the density and the vitality of the superjacent layers, which, in consequence of the former property, do not soften and permit pointing, and, because of the latter, do not slough and thus give exit to the pus, which therefore may extend in the line of least resistance,—*i.e.*, along the loose subaponeurotic layer. Wounds involving either the muscle or its aponeurosis, if transverse to the direction of their fibres, gape widely. Their healing will be hastened by firm bandaging of the whole cranium so as to control and limit the movements of the scalp.

3. The *occipito-frontalis muscle and aponeurosis ;* 4, the *superficial fascia ;* 5, the *skin*. These three layers are so intimately blended that from the practical stand-point they may be considered together. The thin aponeurosis is tied to the skin (which is here thicker than anywhere else in the body) by dense, inelastic, perpendicular and oblique fibres of connective tissue, enclosing little shot-like masses of fat. This area is very vascular, almost all the vessels of the scalp being found in it adherent to the cellular-tissue walls of the fat-containing compartments. As a result of these anatomical conditions it is found that (1) suppuration is very limited in extent ; (2) superficial infections (such as erysipelatous dermatitis) are accompanied by but little swelling ; (3) incised wounds do not gape ; (4) lacerated and contused wounds are not followed by sloughing, which is also rare as a result of continuous pressure, as from bandages ; (5) hemorrhage after wounds is abundant and is persistent because of the adherence of the vessel-walls to the subcutaneous layer of fascia, which prevents both their retraction and contraction ; (6) collections of blood after contusions may, like the deeper ones already described, become very firm at the periphery,—in this case from an excess of fibrinous exudate and from the presence of particles of displaced fat,—while the inelastic fibres of cellular tissue (from among which the fat particles have been driven out by the force of the blow) remain depressed in the centre ; these appearances have not infrequently led to a

mistaken diagnosis of fracture of the skull; (7) lipomata are rare, as in the only layer in which fat is found its abnormal growth is resisted by the density of the surrounding connective tissue.

Baldness affects especially the area of the scalp which directly overlies the occipito-frontal aponeurosis. It is attributed (Elliott) largely to the lack of muscular fibres in this region, so that the skin is not "exercised" and the lymph-current is made to depend chiefly on gravity. The density of the superficial fascia connecting the skin and the aponeurosis allies it with that of the palmar and plantar regions, in both of which similarly dense fascia is found and hair is absent.

Dermoids are common over the anterior fontanelle and the occipital protuberance because the early contact of the skin and dura mater continues longest in these regions. "Should the skin be imperfectly separated, or a portion remain persistently adherent to the dura mater, it would act precisely as a tumor germ and give rise to a dermoid cyst" (Sutton).

Wens are also common on account of the presence of large numbers of sebaceous glands. In removing such growths, if the dissection is carried close to the sac, the subaponeurotic layer will not be opened and all danger, even in case of infection, will be minimized.

So-called "horns" are found here with relative frequency by reason of the number of sebaceous glands.

Emphysema of the scalp may occur as a complication of fractures involving the pharynx, the frontal sinuses, or the ethmoid or nasal bones. The air infiltrates either the subaponeurotic or subcutaneous cellular tissue.

Pneumatocele of the frontal region is very rare, but has occurred in a few cases as a result of a communication between the nasal cavity and bony defects in the anterior wall of the frontal sinuses. The swelling is soft, elastic, and resonant, and is made more tense by forced expiration, less so by pressure. The entrance and escape of air may be heard on auscultation. The air is always beneath the pericranium.

Syphilis, tuberculosis, carcinoma, and sarcoma may affect the scalp primarily, and are mentioned in the order of frequency of occurrence.

Cirsoid aneurism is especially frequent upon the scalp.

The Temporal Region.—Here the skin is thinner and less intimately adherent to the subcutaneous fascia than in the occipito-frontal region; that fascia also is somewhat less closely connected to the aponeurosis beneath. Hemorrhage between these layers is therefore more easily controlled by the usual process of picking up and tying the vessel, the walls of which will be found freer from attachments to the bundles of fascia.

The fascia over the temporal muscle itself is of such strength and thickness that abscesses beneath it rarely point above the zygoma, but are directed into the pterygo-maxillary region and thence into the pharynx or into the neck, or along the anterior temporal muscular fibres to the coronoid process and thence into the mouth. Abscesses above it have no special anatomical peculiarities.

The fat in the temporal fossa is abundant, and is found in the subcutaneous fascia, between the two layers of the temporal fascia, and directly upon the muscle itself. The disappearance of this fat in diseases attended by emaciation causes the characteristic unnatural prominence of the zygoma and apparent deepening of the temporal fossæ.

The temporal muscle should be considered with the pterygoids in their relation to fracture of the ramus and coronoid process (pages 245, 493), to dislocation of the inferior maxilla (pages 246, 493), and to resection of that bone.

The pericranium of this region is thinner and more adherent than that of the occipito-frontal region, and the subpericranial connective tissue is absent; hence subperiosteal abscess or hæmatoma is practically unknown.

The region may be invaded by tumors originating in the orbit and spreading through the spheno-maxillary fissure or through the thin orbital process of the malar bone.

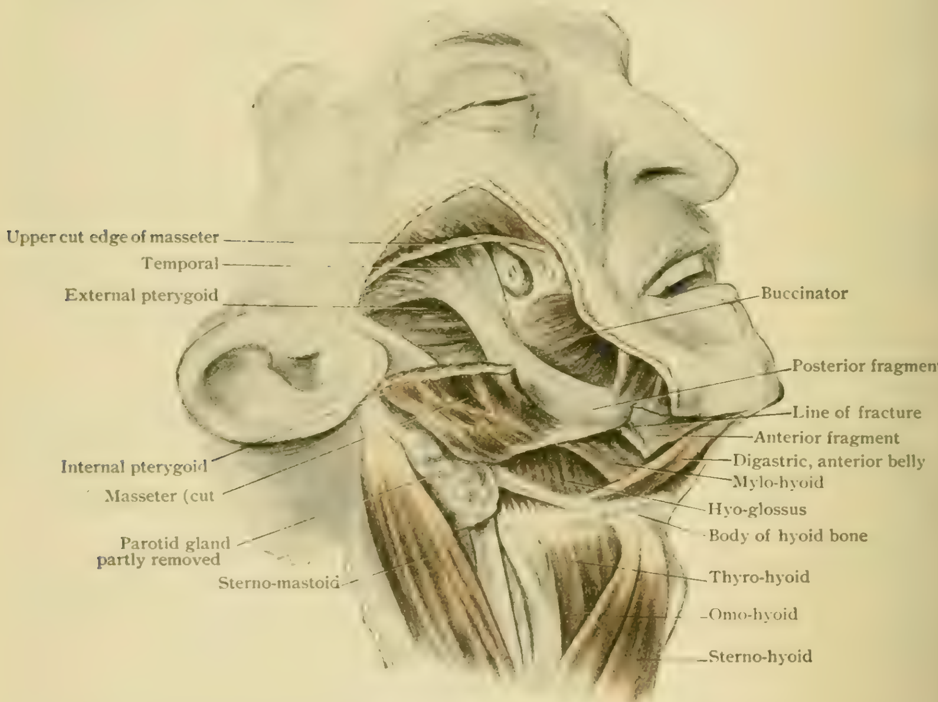
Trephining and other operations in this region are so closely related to intra-cranial diseases and middle-ear disease that they will be considered in that relation (page 1509).

The Mastoid Region.—For the same reasons the practical anatomy of the soft parts covering the remaining region of the skull—the mastoid—will be taken up later (page 1508).

The Face. The skin of the forehead and cheeks is thin and vascular and the cellular tissue beneath is loose. Therefore wounds bleed freely but unite rapidly; sloughing is rare; cellulitis tends to spread; œdema is common; superficial infections (favored by the constant exposure of the region) are attended by much redness and swelling and little pain; if they result in abscess, it is not apt to attain a large size, as the delicacy of the skin permits of early pointing. On the other hand, necrotic processes (as in cancrum oris) once established in the loose cellular tissue and fat of the cheeks, run a rapid and destructive course, and may be followed by great disfigurement and by limitation of the motions of the inferior maxilla.

Abscesses beneath the buccinator aponeurosis, like fatty growths in the same situation, project towards the cavity of the mouth; they should be opened through the mucous membrane.

FIG. 505.



Dissection of fracture of body of mandible, showing displacement produced by muscular action.

Over the lower third of the nose the skin is closely adherent, as it is over the chin, where it is also very dense. Infections in those regions are therefore exceptionally painful (page 246). The vascularity and mobility of the skin of the forehead and of the cheeks make it especially useful in plastic operations upon the region of the nose and mouth.

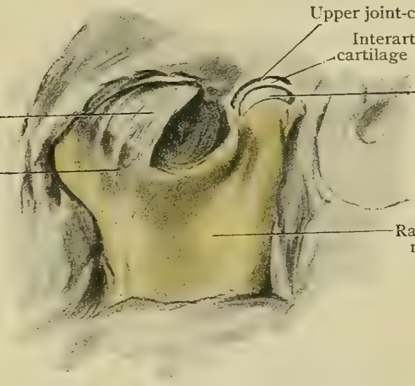
On account of the rich blood-supply, nævi are common on all parts of the face, as, by reason of the numerous sweat and sebaceous glands, are acneiform eruptions.

Lupus and malignant pustule are frequent and grave forms of local infection; rodent ulcer (epithelioma) is common; while on the forehead the early syphilitic roseola or papule (corona veneris) and about the lips and nose the later tubercular syphilide are often seen.

Lipomata, in spite of the considerable quantity of fat in the subcutaneous tissue, are very rare. The mass of fat between the buccinator and masseter muscles—

"boule de Bichat," "sucking cushion"—is believed to receive and distribute the increased atmospheric pressure which follows the establishment of a partial vacuum in the mouth during sucking. It thus aids in preventing the buccinator from being carried in between the alveoli. It is relatively smaller in adults than in infants and in the latter does not much diminish in size, even in the presence of emaciation, when the general subcutaneous fat has largely disappeared (Ranke). Sutton says, "The sucking cushions sometimes enlarge in adults and simulate more serious species of tumors, and it is curious that in some of the recorded cases the enlargement has been associated with the impaction of a salivary calculus in the duct of the parotid gland."

FIG. 506.

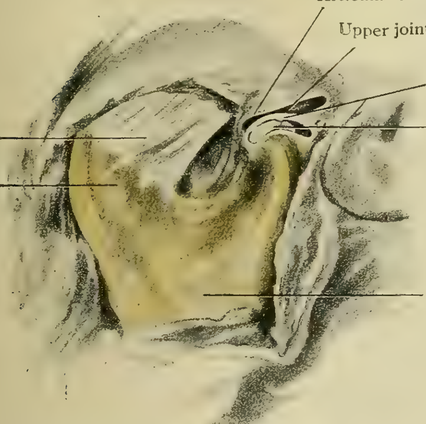


Dissection showing relations when mandible rests within glenoid fossa; outer part of capsular ligament has been cut away, exposing upper and lower joint-cavities.

The importance of avoiding conspicuous scars on the face leads the surgeon to make his incisions, whenever possible, either in or parallel with the lines of the natural furrows due to the insertion of some of the facial muscles into the skin itself, or in the shadow of overhanging parts, as beneath the upper brow or the lower edge of the inferior maxilla. For a reason not understood, but possibly associated with the difficulty in securing rest, combined with the large vascular supply, cicatricial overgrowth and true keloid are both relatively common after wounds of the face.

In fracture of the inferior maxilla the irregularity in the horizontal planes of the two fragments (the anterior being the lower) is due to (*a*) the weight of the chin and opposite side of the jaw; (*b*) the action on the anterior fragment of the digastric and other depressors of the chin; and (*c*) the effect of the posterior fibres of the temporal, the internal pterygoid, and the superficial fibres of the masseter in elevating the posterior fragment (Fig. 505).

FIG. 507.



Dissection showing relations when mandible is depressed and carried forward upon articular eminence; capsular ligament is stretched in consequence.

In fracture of the ramus there is little displacement, as the bone lies between the two muscular planes of the masseter and internal pterygoid and is splinted by them. In fracture of the neck of the condyle the upper fragment is drawn upward and forward by the external pterygoid; the remainder of the jaw is somewhat elevated by the masseter, temporal, and internal pterygoid. The difficulty in approximation of the fragments may result in excess of callus, which greatly interferes with the subsequent movements of the temporo-maxillary articulation.

The mechanism of dislocation of the lower jaw has already been described (page

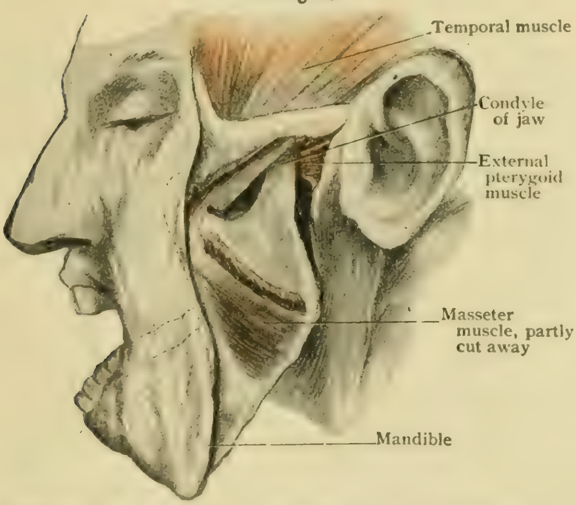
246), but can now be better understood. It should be remembered that the muscles of mastication are exceptionally irritable and are all supplied by the motor branch of the mandibular division of the fifth nerve. When the mouth is opened very widely, as in yawning, or in an effort to take an unusually large bite, the deep posterior vertical fibres of the masseter (which are the only ones attached to the ramus and aiding in closing the mouth that do not run forward as well as upward) are carried behind the centre of motion, so that their contraction tends still further to open the mouth or to keep it open. Reflex contraction from overstretching is excited in the general group, and the external pterygoid acting with most advantage in that position, draws the condyle into the zygomatic fossa, where it is held by the masseter and internal pterygoid.

"Noisy movement" of the temporo-maxillary joint is often due to weakness of the muscles of mastication, permitting the joint surfaces to fall apart as the result of the slight lengthening of the ligaments produced in time by the weight of the jaw.

Paralysis and spasm of the facial and masticatory muscles will be considered in relation to the nerves supplying them (pages 1255, 1248).

The most frequent congenital defect of the muscles of the face is in connection with harelip, in which deformity the portion of the orbicularis oris corresponding to the cleft is absent.

Fig. 508.



Dissection showing position of dislocated jaw, condyle having slipped in front of articular eminence.

Dermoids are not infrequently found at the angles of the orbit, in the cheeks near the corner of the mouth, in the naso-labial furrows, at the root of the nose, and in the mid-line of the chin. Reference to the embryology of the face will show that these are localities in which epiblastic inclusion is likely to occur.

Marked congenital asymmetry of the face may occur from failure of developmental processes.

Landmarks.—Just within the mid-point of a line drawn from the mastoid process to the external occipital protuberance the occipital artery can be felt as, with the great occipital nerve, it enters the scalp on its way to the vertex.

The superficial temporal artery can be felt, and often can be seen where it runs over the base of the zygoma in front of the ear. Its vein and the auriculo-temporal nerve are just behind it. The division of the artery into its anterior and posterior branches takes place about 5 cm. (2 in.) above the zygoma. These branches are easily palpable on the firm underlying structures, and thus afford testimony as to the presence or absence of arterial degeneration. In old persons they are often tortuous and plainly visible, especially the anterior branch where it crosses the anterior portion of the temporal muscle. The region is a frequent seat of cirsoid aneurism.

At the junction of the middle with the inner third of the supra-orbital bony margin the supra-orbital notch may be felt. From this point the supra-orbital nerve and artery pass almost directly upward, crossing the orbital margin. Between that point and the root of the nose the frontal artery and supratrochlear nerve ascend and the frontal vein descends.

The movement of the condyle of the inferior maxilla up to the summit of the eminentia articularis when the mouth is open and the external pterygoid contracts, and its return into the glenoid cavity when that muscle is relaxed and the mouth is closed, can plainly be felt.

The relation of many of the bony points to the overlying soft parts has been described (page 246).

The shape of most of the muscles cannot be separately distinguished. Comparison of a skull with a partially dissected head will show, however, that over the vault of the cranium from the supra-orbital ridges to the nucha the general shape of the skull determines the surface form during life, the flattened muscles and aponeurosis closely conforming to it. In the temporal regions, in spite of the deep bony fossa, the triangular muscle and the accompanying fat (page 491) make the surface in vigorous, well-nourished persons slightly convex. The outlines of the muscle can be seen when it is in contraction, especially the portion anterior to the hairy scalp.

On the face the characteristics that distinguish the individual are due largely to the presence of muscles and of subcutaneous fat. The edge of the orbit and the naso-frontal junction are covered and given rounded outlines by the orbicularis palpebrarum and the pyramidalis nasi. The muscles running from the malar bone and maxilla to the upper lip aid the buccinator and the fat of the cheek in filling up the great hollows beneath the malar prominences. The orbicularis oris gives shape and expression to the mouth. The masseter fills out the posterior portion of the cheek and becomes visible in outline when in firm contraction, especially the vertical anterior border, just in front of which the facial artery crosses the inferior maxilla.

As nearly all the facial muscles have fibres of insertion into the facial integument, their influence upon expression and upon the creases and folds that become permanent as "wrinkles," "crows' feet," etc., is apparent.

III. THE VAGO-ACCESSORY MUSCLES.

The muscles supplied by the glosso-pharyngeal, vagus, and spinal accessory nerves may be grouped together both on account of their relations in the adult and on account of the intimate relations which exist between the three nerves. The glosso-pharyngeal and vagus correspond to the posterior branchial arches, the glosso-pharyngeal to that represented in the adult by the greater cornu of the hyoid bone and the vagus to those represented by the laryngeal cartilages. Consequently we find the muscles supplied by these nerves to be those associated with the pharynx and larynx, one of the muscles of the soft palate, the levator palati, being also included in the group. The pharyngeal muscles, for the most part, are supplied from the pharyngeal plexus, into which fibres from both the glosso-pharyngeal and vagus nerves enter. The laryngeal muscles, however, are supplied by branches coming directly from the stem of the vagus nerve.

The spinal accessory nerve stands in such intimate relations with the vagus that its nucleus of origin may well be regarded as an extension of that of the vagus, and by the union of a portion of its fibres with those of the vagus to form a common trunk opportunity is afforded for its fibres to participate in the formation of the pharyngeal plexus, and there is evidence pointing to the origin of the fibres of the inferior laryngeal nerve, which supplies the majority of the laryngeal muscles, from the spinal accessory nucleus.

In addition, however, to its participation in the supply of the pharyngeal and, possibly, the laryngeal muscles, the spinal accessory also innervates the trapezius and sterno-mastoid muscles, and these, on account of their relations, must constitute a subgroup distinct from the other vago-accessory muscles.

(*a*) THE MUSCLES OF THE PALATE AND PHARYNX.

1. Stylo-pharyngeus.
2. Levator palati.
3. Azygos uvulæ.
4. Palato-glossus.
5. Palato-pharyngeus.
6. Constrictor pharyngis superior.
7. Constrictor pharyngis medius.
8. Constrictor pharyngis inferior.

1. Stylo-Pharyngeus (Figs. 502, 509).

Attachments.—The stylo-pharyngeus *arises* from the inner surface of the styloid process near its base. It is directed downward, the glosso-pharyngeal nerve

covering its outer surface, passes between the middle and superior constrictors of the pharynx, and, being joined by fibres from the palato-pharyngeus, is *inserted* into the posterior border of the thyroid cartilage and the posterior wall of the pharynx.

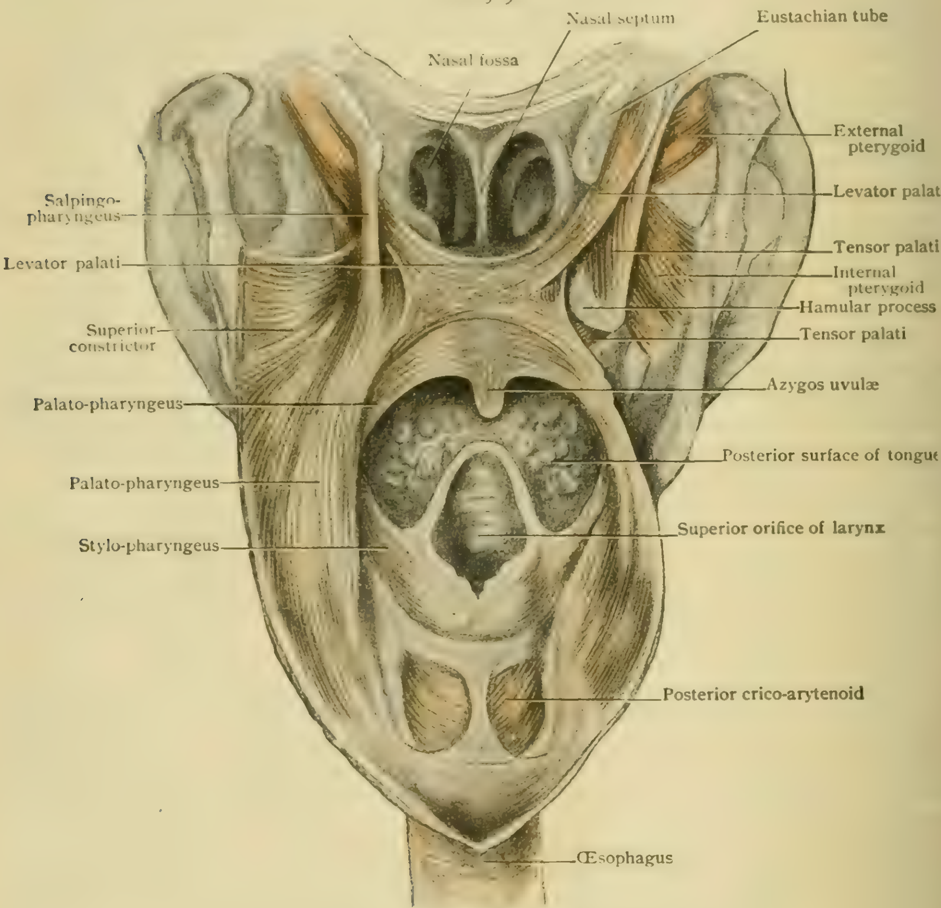
Nerve-Supply.—By a branch of the glosso-pharyngeal nerve.

Action.—To draw upward the posterior wall of the pharynx and the thyroid cartilage.

2. Levator Palati (Fig. 509).

Attachments.—The elevator of the soft palate (**m. levator veli palatini**) *arises* from the under surface of the apex of the petrous portion of the temporal bone and from the cartilaginous portion of the Eustachian tube. It descends obliquely down-

Fig. 509.



Muscles of palate and pharynx, seen from behind; pharynx laid open.

ward and forward, and, broadening out, enters the substance of the soft palate, into the aponeurosis of which it is *inserted*.

Nerve-Supply.—From the pharyngeal plexus by fibres which probably have their origin in the anterior part of the nucleus of the spinal accessory nerve.

Action.—To elevate the soft palate.

3. Azygos Uvulæ (Fig. 509).

Attachments.—The azygos uvulæ (**m. uvulae**), so named on the supposition that it was an unpaired muscle, consists of two narrow slips which *arise* from the

aponeurosis of the soft palate and from the posterior nasal spine. They pass backward and downward, almost parallel with each other, into the uvula to be *inserted* into its aponeurosis.

Nerve-Supply.—From the pharyngeal plexus.

Action.—To raise the uvula.

4. Palato-Glossus (Fig. 1339).

Attachments.—The palato-glossus (**m. glossopalatinus**) is a thin sheet which *arises* from the under surface of the aponeurosis of the soft palate and descends in the anterior pillar of the fauces (**arcus glossopalatinus**) to be *inserted* into the sides of the tongue, mingling with the fibres of the stylo-glossus.

Nerve-Supply.—From the pharyngeal plexus, probably by fibres from the anterior part of the nucleus of the spinal accessory nerve.

Action.—To raise the back part of the tongue and at the same time to narrow the fauces by causing an approximation of the anterior pillars. Acting from below, it will depress the soft palate.

5. Palato-Pharyngeus (Fig. 509).

Attachments.—The palato-pharyngeus (**m. pharyngopalatinus**) *arises* from the aponeurosis of the soft palate, from the posterior border of the hard palate, and also from the lower portion of the cartilage of the Eustachian tube. It passes downward and backward in the posterior pillar of the fauces (**arcus pharyngopalatinus**), internal to the superior and middle constrictors of the pharynx, and is *inserted* into the posterior border of the thyroid cartilage and into the posterior wall of the pharynx. That portion of the muscle which arises from the cartilage of the Eustachian tube is often regarded as a distinct muscle which has been termed the *salpingo-pharyngeus.*

Nerve-Supply.—From the pharyngeal plexus, probably by fibres from the anterior part of the nucleus of the spinal accessory nerve.

Action.—It draws the pharynx and thyroid cartilage upward and at the same time approximates the two posterior pillars of the fauces. Acting from below, it will depress the soft palate.

6. Constrictor Pharyngis Superior (Figs. 501, 510).

Attachments.—The superior constrictor of the pharynx forms a thin quadrilateral sheet whose origin is closely associated with part of that of the buccinator, there being usually some interchange of fibres between the two muscles. It *arises* from the lower part of the posterior border of the internal pterygoid plate and from its hamulus, from the posterior border of the pterygo-mandibular ligament, and is thence continued upon the internal oblique line of the mandible, the mucous membrane of the mouth, and the side of the tongue. The uppermost fibres pass in a curve backward and upward and are *inserted* into the pharyngeal tubercle of the occipital bone, while the remainder unite with the muscle of the opposite side in a median raphe on the posterior wall of the pharynx.

Nerve-Supply.—From the pharyngeal plexus by fibres which probably arise from the anterior portion of the nucleus of the spinal accessory nerve.

Action.—To compress the pharynx.

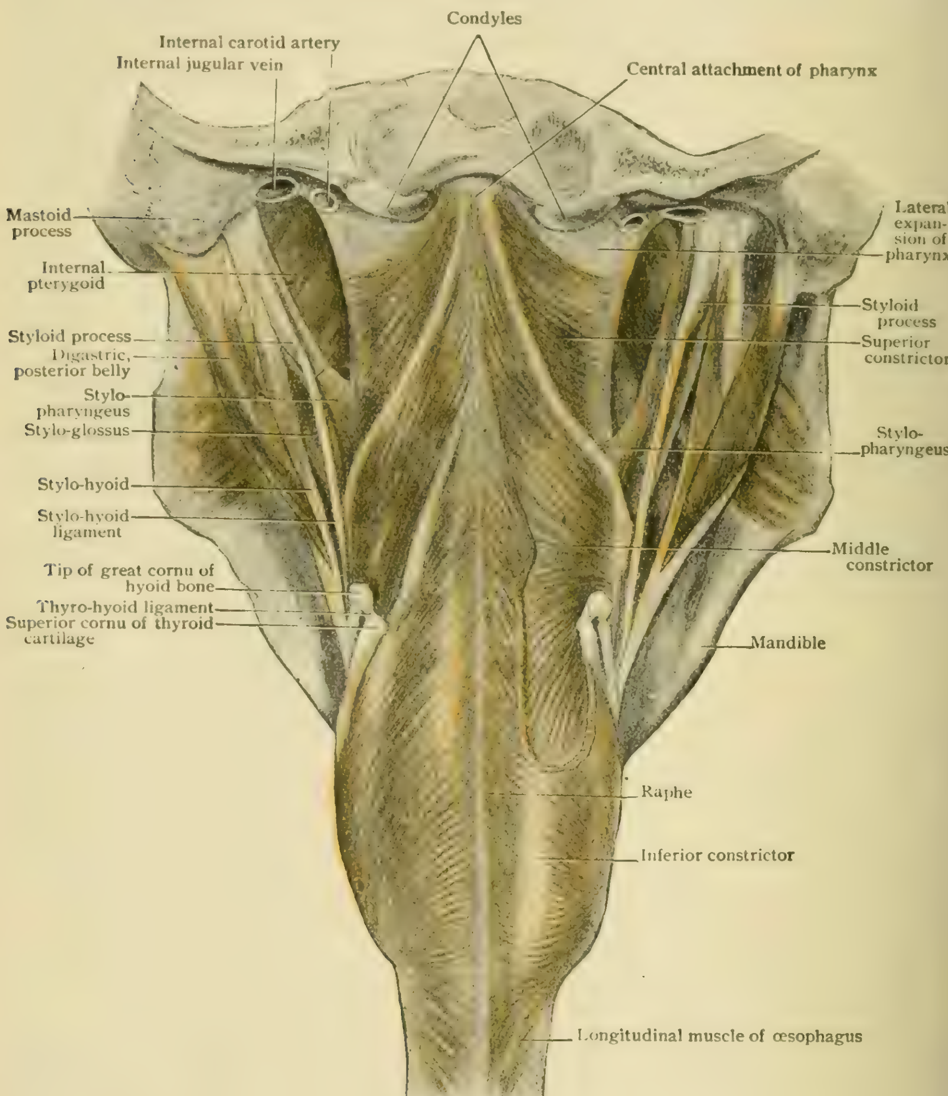
Relations.—Between the uppermost fibres of the muscle and the base of the skull is an interval in which may be seen the levator palati and the Eustachian tube. This interval has been termed the *sinus of Morgagni*, and is closed by a sheet of connective tissue termed the **fascia pharyngobasilaris**, which is an upward prolongation to the base of the skull of the pharyngeal portion of the bucco-pharyngeal fascia (page 488).

Externally the superior constrictor is in relation above with the internal carotid artery, the vagus nerve, and the cervical sympathetic, and below with the upper part of the middle constrictor and the stylo-pharyngeus. Internally it is lined by mucous membrane throughout the greater part of its extent, being in relation, however, with the tonsil and the palato-pharyngeus muscle.

Variations.—A considerable amount of independence may exist between the bundles of fibres coming from different portions of the line of origin, and the muscle has consequently been described as consisting of various portions to which the terms *pterygo-pharyngeus*, *bucco-pharyngeus*, *mylo-pharyngeus*, and *glosso-pharyngeus* have been applied.

Not infrequently a bundle of fibres is to be found arising from the basilar portion of the occipital bone or even from the inferior surface of the petrous portion of the temporal or the spine of the sphenoid, and passing downward to be inserted along with the pharyngo-palatinus. A bundle which passes from the cartilaginous portion of the Eustachian tube to be inserted with the palato-pharyngeus has been termed the *salpingo-pharyngeus*.

FIG. 510.



Muscles of pharynx from behind; portion of inferior constrictor has been removed.

7. Constrictor Pharyngis Medius (Fig. 510).

Attachments.—The middle constrictor of the pharynx is a fan-shaped sheet which *arises* from the stylo-hyoid ligament and both cornua of the hyoid bone. The fibres pass backward to be *inserted* into the pharyngeal raphe, the upper fibres

overlapping the lower part of the superior constrictor and extending in some cases almost to the occipital bone, while the lower fibres are overlapped by the inferior constrictor.

Nerve-Supply.—From the pharyngeal plexus, probably by fibres from the anterior portion of the spinal accessory nucleus. It is said to be supplied also by the glosso-pharyngeal nerve.

Action.—To compress the pharynx.

Variations.—As in the case of the superior constrictor, the fibres from different parts of the origin may have considerable independence. Thus the fibres from the greater cornu of the hyoid have been recognized as a muscle, the *cerato-pharyngeus*, distinct from the remainder, to which the term *chondro-pharyngeus* has been applied.

8. Constrictor Pharyngis Inferior (Figs. 501, 510).

Attachments.—Like the middle constrictor, the inferior is also a fan-shaped sheet and *arises* from the outer surface of the thyroid and cricoid cartilages of the larynx. The fibres radiate backward to be *inserted* into the pharyngeal raphe, the upper ones overlapping the lower part of the middle constrictor, while the lower ones mingle with the musculature of the œsophagus.

Nerve-Supply.—From the pharyngeal plexus, probably through fibres from the anterior part of the nucleus of the spinal accessory. It is said to receive also fibres from the vagus through both the superior and inferior laryngeal nerves.

Action.—To compress the pharynx. The three constrictors of the pharynx play important parts in the final acts of deglutition, forcing the food towards the œsophagus. They are also important agents in producing modulations of the voice, since the pharynx may be regarded as forming a resonator, alterations of whose form will naturally result in modifications of voice.

Variations.—The portions of the muscle arising from each of the two laryngeal cartilages may be more or less distinct and have been termed the *thyro-pharyngeus* and *crico-pharyngeus*.

(*b*) THE MUSCLES OF THE LARYNX.

The muscles of the larynx will be considered in connection with the description of that organ (page 1824).

(*c*) THE TRAPEZIUS MUSCLES.

1. Sterno-cleido-mastoideus. 2. Trapezius.

This group includes but two muscles, the trapezius and sterno-cleido-mastoid, which extend from the skull to the pectoral girdle. Both are in reality compound muscles, formed by the fusion of fibres derived from the branchiomeres supplied by the spinal accessory with portions of the myotomes supplied by the second, third, and fourth cervical nerves. Strictly speaking, therefore, they belong only partially to the series of branchiomeric muscles, but the union of the elements derived from the two sources is so intimate that any attempt to distinguish them in a brief description of the muscles would tend to confusion.

1. Sterno-Cleido-Mastoideus (Fig. 541).

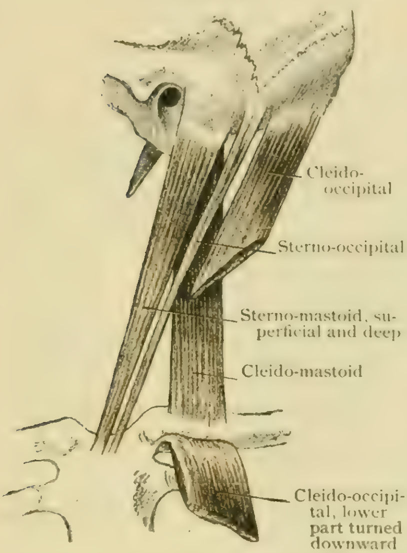
Attachments.—The sterno-mastoid is attached below by two heads to the sternum and the clavicle. The *sternal head arises* by a strong rounded tendon from the anterior surface of the manubrium sterni, while the *clavicular head* is more band-like, and takes *origin* from the upper surface of the sternal end of the clavicle. The two heads are directed upward and backward, the clavicular head gradually passing beneath the sternal one, and the two, eventually fusing, are *inserted* into the mastoid process of the temporal bone and into the outer part of the superior nuchal line.

Nerve-Supply.—The external branch of the spinal accessory and the second and third cervical nerves.

Action.—The two muscles of opposite sides, acting together, will draw the head forward, thus bending the neck. Acting singly, each muscle will tend to draw the head towards its own side and at the same time to rotate it towards the opposite side.

Relations.—Superficially the muscle is covered by the platysma, and is crossed obliquely by the external jugular vein and in varying directions by the superficial branches of the cervical plexus. It covers, above, the upper part of the posterior belly of the digastric, the splenius capitis, the levator scapulæ and the scaleni, and below it crosses the omo-hyoid and covers the lower attachments of the sterno-hyoid and sterno-thyroid. It also covers the common carotid artery and the lower portions of the external and internal carotids, the facial and internal jugular veins, the cervical plexus, and the lateral lobe of the thyroid gland.

FIG. 511.



Quadricipital type of sterno-mastoid, showing the components of the muscle. (*After Maubrac.*)

Variations.—Considerable variation exists in the amount of fusion of the two heads, their complete distinctness being of so frequent occurrence as to be regarded as normal by some authors. But, in addition to these two portions, the muscle presents frequently a separation into other parts, and comparative anatomy reveals a primary constitution of the muscle from at least five distinct portions, any one or more of which may appear as distinct bundles (Fig. 511). These portions are arranged in two layers, the superficial one consisting of a *superficial sterno-mastoid*, a *sterno-occipital*, and a *cleido-occipital* portion, while the deep one is formed by a *deep sterno-mastoid* and a *cleido-mastoid* portion, the names applied indicating the attachments of the various bundles.

Occasionally the lower portion of the muscle is traversed by a tendinous intersection, a peculiarity of interest in connection with the formation of the muscle by the fusion of portions derived from different myotomes.

2. TRAPEZIUS (Figs. 512, 559).

Attachments.—The trapezius is the most superficial muscle upon the dorsal surface of the body, and is a triangular sheet whose base corresponds with the mid-dorsal line. The two muscles of opposite sides being thus placed base to base, form a rhomboidal sheet which covers the nape of the neck and the upper part of the back and shoulders, resembling somewhat a monk's cowl, whence the name *cucullaris* sometimes applied to the muscle.

It *arises* above from the superior nuchal line and the external occipital protuberance, and thence along the ligamentum nuchæ and the spinous processes of the seventh cervical and all the thoracic vertebræ, together with the supraspinous ligaments. The upper fibres pass downward and outward, the middle ones directly outward, and the lower ones upward and outward, and are *inserted*, the upper ones into the outer third of the posterior border of the clavicle, the middle ones into the inner border and upper surface of the acromion process and the upper border of the spine of the scapula, and the lower ones into a tubercle at the base of the scapular spine.

Throughout the greater part of its length the origin of the muscle is by short tendinous fibres intermingled with muscle-tissue, but from about the middle of the ligamentum nuchæ to the spinous process of the second thoracic vertebra it is entirely tendinous. Furthermore, throughout the upper half of this portion of the origin the tendinous fibres gradually increase in length and throughout its lower half they again diminish, so that there is formed by the two muscles of opposite sides, in this region,

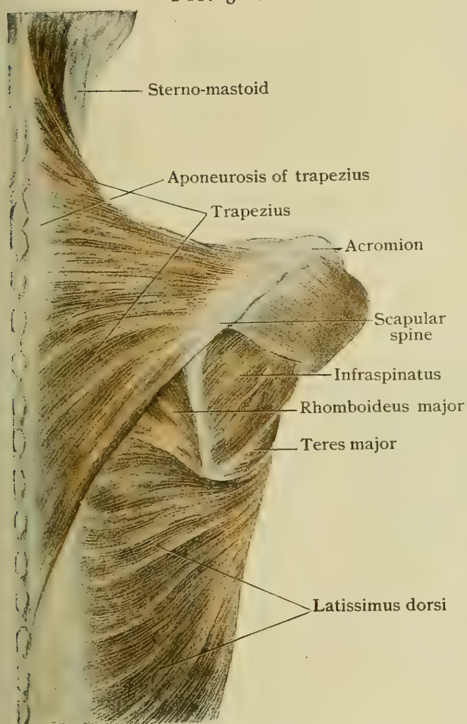
a well-marked oval or rhomboidal tendinous area, which has been termed the *oval aponeurosis.*

In their course to their insertion the lower fibres pass over the smooth surface at the base of the spine of the scapula, and sometimes a bursa mucosa is developed between the bone and the muscle.

Nerve-Supply.—From the external branch of the spinal accessory and from the third and fourth cervical nerves.

Action.—Acting from above, the upper fibres draw upward the point of the shoulder, while, acting from below, they draw the head backward. The middle and lower fibres draw the scapula towards the mid-dorsal line and at the same time rotate it so as to raise the point of the shoulder.

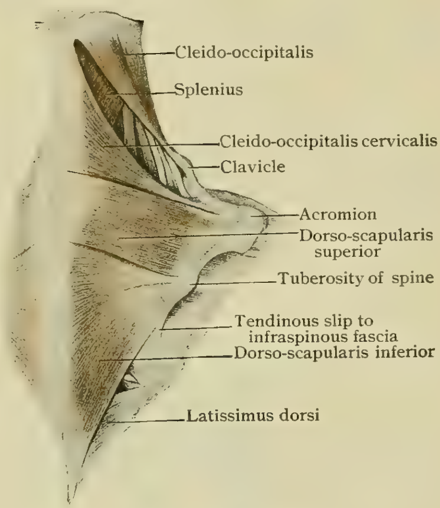
FIG. 512.



Superficial dissection of back, showing trapezius and adjacent muscles.

Variations.—Like the sterno-mastoid, the trapezius is a compound muscle consisting of three distinct portions. That portion of the muscle which inserts into the tuberosity of the scapular spine represents what is termed in the lower mammals the *dorso-scapularis inferior,* while the portion which inserts into the spine and acromion process represents the *dorso-scapularis superior.* The clavicular portion, on the other hand, is in the lower forms associated with the cleido-occipitalis element of the sterno-cleido-mastoid, and may therefore be termed the *cleido-occipitalis cervicalis.*

FIG. 513.



Components of human trapezius muscle. (*Streissler.*)

Indications of this triple constitution are to be seen in a more or less distinct separation of the clavicular portion of the muscle from the rest and, less frequently, by a separation of the lower from the middle portion (Fig. 513). Occasionally, too, bundles pass from the anterior border of the clavicular portion to join the cleido-occipitalis portion of the sterno-cleido-mastoid, indicating the common origin of the two muscles. Variations likewise occur in the extent of the spinal attachment of the trapezius, owing to the reduction of one or other of its parts, and it may be remarked that this attachment usually extends lower in the muscle of the right side than in that of the left.

Of especial interest from the comparative stand-point is the occasional existence of a bundle of fibres which lies beneath the cervical portion of the trapezius, and is attached at one extremity to the outer end of the clavicle or to the acromion process and above to the transverse processes of some of the upper cervical vertebræ, usually the atlas and axis. It is apparently the equivalent of the *omo-transversarius* of the lower mammals, a muscle which is closely associated with the members of the trapezius group.

THE METAMERIC MUSCLES.

A. THE AXIAL MUSCLES.

As has been pointed out, the history of the anterior two groups of myotomes, supplied by cranial nerves, differs somewhat from that of the remaining ones, and it is convenient, therefore, to consider the muscles derived from these myotomes separately from the rest.

I. THE ORBITAL MUSCLES.

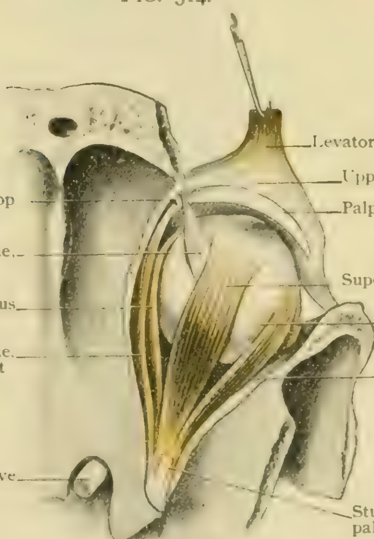
1. Levator palpebræ superioris.
2. Rectus superior.
3. Rectus internus.
4. Rectus inferior.
5. Rectus externus.
6. Obliquus superior.
7. Obliquus inferior.

The most anterior of the persistent myotomes are three in number, supplied by the oculo-motor, trochlear, and abducent nerves. They give rise to the muscles situated in the orbit.

1. Levator Palpebræ Superioris (Fig. 516).

Attachments.—The levator palpebræ superioris is a rather slender muscle which lies in the greater portion of its course immediately beneath the periosteal lining of the roof of the orbit. It *arises* at the back of the orbit, a short distance above the upper margin of the optic foramen, and is directed forward, broadening as it goes, to be *inserted* by a broad aponeurosis principally into the upper border of the tarsal plate of the upper eyelid, the uppermost fibres mingling somewhat with those of the palpebral portion of the orbicularis oculi.

Fig. 514.



Ocular muscles seen from above after removal of roof of orbit; elevator of upper eyelid has been cut and reflected forward.

The aponeurosis by which the levator inserts into the tarsal plate is largely composed of non-striated muscular fibres, which constitute what has been termed the *orbito-palpebral* muscle. This is triangular in shape, with the truncated apex united to the levator and with the base attached to the external palpebral raphe, the tarsal plate of the upper eyelid, and the internal palpebral ligament.

Nerve-Supply.—From the oculo-motor nerve.

Action.—To draw the upper eyelid upward and backward.

Relations.—Immediately above the levator palpebræ superioris, between it and the periosteum of the roof of the orbit, are the trochlear and frontal nerves and the supra-orbital vessels. Below it rests upon the medial half of the rectus superior.

2. Rectus Superior (Fig. 514).

Attachments.—The superior rectus *arises* from the upper portion of a fibrous ring termed the *annulus of Zinn* (**annulus tendineus communis**), which surrounds the optic foramen and is formed by a thickening of the orbital periosteum in that region. Thence the muscle is directed forward over the eyeball and is *inserted* into the sclera a little above the upper margin of the cornea.

Nerve-Supply.—From the oculo-motor nerve.

Action.—To rotate the eyeball so that the pupil is directed upward and at the same time somewhat inward.

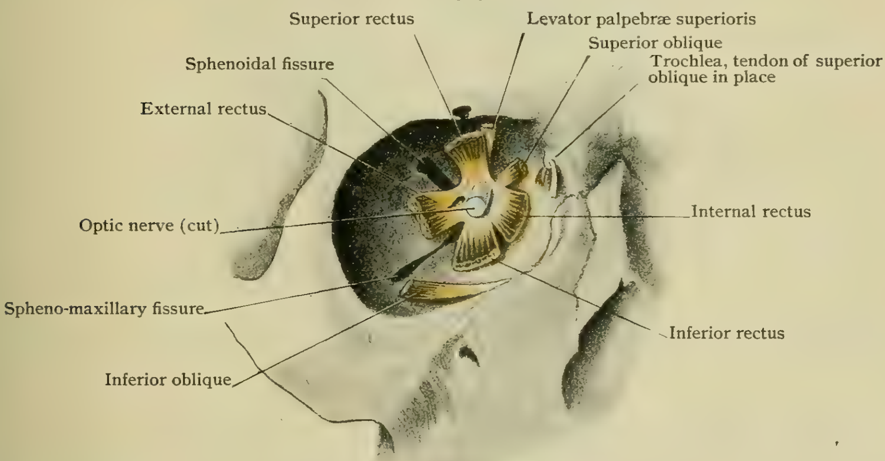
3. Rectus Internus (Fig. 514).

Attachments.—The internal rectus (**m. rectus medialis**) *arises* from the inner portion of the annulus tendineus communis and passes forward along the inner wall of the orbit to be *inserted* into the sclera a short distance behind the inner margin of the cornea.

Nerve-Supply.—From the oculo-motor nerve.

Action.—To rotate the eyeball so that the pupil is directed inward.

Fig. 515.



Right orbit seen from before, showing stumps of ocular muscles attached to common tendinous ring of origin.

4. Rectus Inferior (Fig. 516).

Attachments.—The inferior rectus *arises* from the lower portion of the common tendinous ring, its line of origin being continuous with that of the rectus internus. It is *inserted* into the sclera a short distance below the inferior margin of the cornea.

Nerve-Supply.—From the oculo-motor nerve.

Action.—To rotate the eyeball so that the pupil is directed downward and at the same time somewhat outward.

5. Rectus Externus (Fig. 514).

Attachments.—The external rectus (**m. rectus lateralis**) *arises* by two heads, one of which is attached to the lower and outer portion of the common tendinous ring and to the spine on the lower border of the sphenoidal fissure, and the other to the upper and outer part of the common tendinous ring. It passes along the outer wall of the orbit and is *inserted* into the sclera a little behind the outer border of the cornea.

Nerve-Supply.—From the abducens or sixth nerve.

Action.—To rotate the eyeball so that the pupil is directed outward.

Relations.—Between the two heads of the external rectus there pass the oculomotor, nasal, and abducent nerves and the ophthalmic vein.

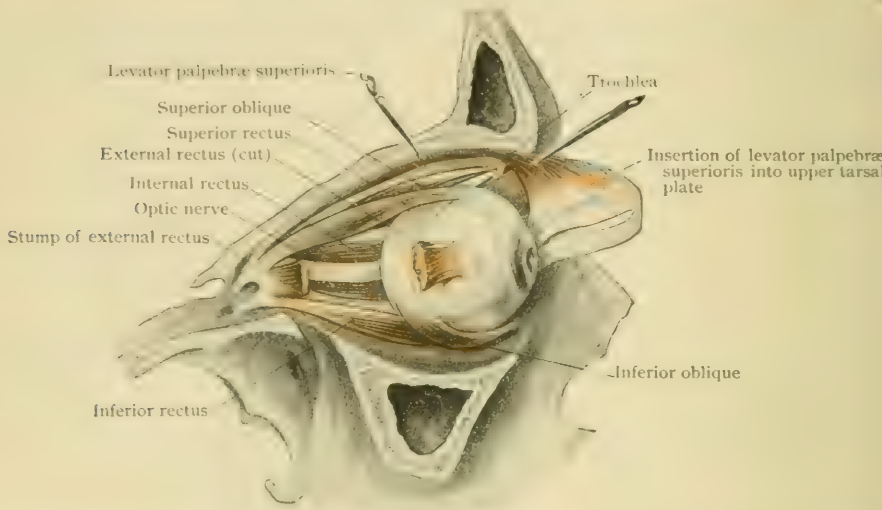
6. Obliquus Superior (Figs. 514, 516).

Attachments.—The superior oblique muscle of the eyeball *arises* a little in front of the inner part of the optic foramen and passes forward along the upper and inner wall of the orbit to terminate in a round tendon which passes through a tendinous loop, the *trochlea*, attached to the fovea trochlearis of the frontal bone. Thence it is reflected outward, downward, and backward, and, passing beneath the superior rectus, is *inserted* into the sclera beneath the outer margin of that muscle and at about the equator of the eyeball.

Nerve-Supply.—From the trochlearis or fourth nerve.

Action.—To rotate the eyeball so that the pupil is directed inward and downward.

Fig. 516.



Lateral view of ocular muscles after removal of outer wall of orbit; elevator of upper lid has been pulled upward and inward.

7. Obliquus Inferior (Fig. 516).

Attachments.—The inferior oblique muscle *arises* near the margin of the orbit from a small depression on the orbital surface of the maxilla. It is directed outward, backward, and upward, and, passing between the inferior rectus and the floor of the orbit, is *inserted* into the sclera a little behind the equator of the eyeball and under cover of the external rectus.

Nerve-Supply.—From the oculo-motor nerve.

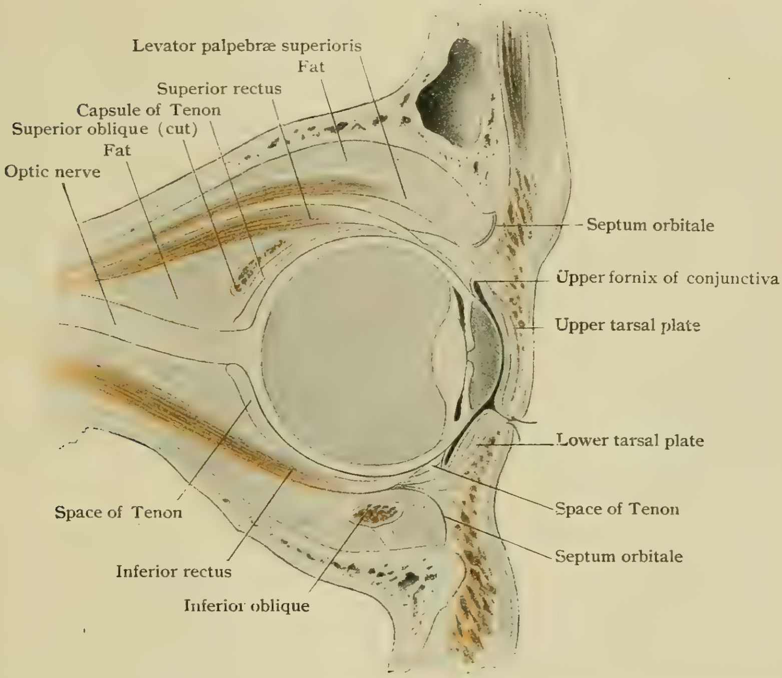
Action.—To rotate the eyeball so that the pupil is directed upward and outward.

Fasciæ of the Orbit.—The muscles, nerves, and vessels of the orbit are embedded in a mass of loose areolar tissue which, abundantly intermingled with a soft fat, completely fills the orbital cavity. Around the vessels, nerves, and muscles this areolar tissue condenses to form their sheaths, and a special condensation, the *capsule of Tenon* (**fascia bulbi**), surrounds the posterior four-fifths of the eyeball, forming a socket for it. The inner surface of this capsule is smooth and is united to the outer surface of the sclera only by lax and slender bands of fibres which traverse a distinct lymph-space termed the *space of Tenon* (**spatium interfasciale**), which intervenes between the capsule and the eyeball, thus facilitating the movements of the latter in the socket. Posteriorly the capsule is continuous with the sheath of the optic nerve and anteriorly it joins with the conjunctiva anterior to the line of insertion of the rectus muscles into the sclera. The tendons of the rectus muscles consequently perforate the capsule, which is prolonged backward upon the tendons for a short distance,—in the case of the superior oblique as far as the trochlea,—and then becomes continuous with the areolar sheaths of the muscles which are intimately

adherent to the muscle-tissue and constitute the **fasciæ musculares.** These fasciæ are somewhat thicker in their anterior portions than more posteriorly, and give off prolongations to neighboring parts. From the fascia of the rectus superior a prolongation passes to join the tendon of the levator palpebræ superioris, and one from the rectus inferior passes to the lower border of the tarsal plate of the lower eyelid, these two recti thus acquiring a certain amount of action upon the eyelids. From the lateral surface of the fascia of the external rectus a rather strong prolongation is given off which attaches to the orbital surface of the zygomatic arch, forming what has been termed the *external check ligament* of the eyeball, while from the medial surface of the fascia of the internal rectus a similar, although somewhat laxer, prolongation passes to the crest of the lachrymal bone and the reflected portion of the internal palpebral ligament.

The Movements of the Eyeball.—The four recti muscles of the eyeball may be regarded as forming a cone whose apex is at the annulus tendineus communis

Fig. 517.



Diagrammatic sagittal section through orbit, showing relations of fascia to muscles, eyeball, and orbital wall.

and the base at the insertions of the muscles into the sclera. The line joining the insertions of the muscles is not, however, a circle, but rather a spiral, the insertion of the internal rectus being nearest to and that of the rectus superior farthest from the edge of the cornea. The axis of the cone does not correspond in direction with the antero-posterior axis of the eyeball, but, owing to the divergence of the axes of the two orbits, is inclined to it from within outward at an angle of about 20°.

It follows from this that during the contraction of either the superior or inferior rectus the axis of rotation of the eyeball will not coincide with its transverse axis, but will be inclined to it (Fig. 518), and consequently the action of either of these muscles in directing the pupil upward or downward will be complicated by a certain amount of oblique movement, in the one case inward and in the other case outward. In producing purely upward or downward movements of the pupil the rectus muscles are associated with the oblique ones, the coördination of the inferior oblique with the superior rectus producing a purely upward rotation, while that of the superior oblique with the inferior rectus produces a purely downward movement.

It has been demonstrated also that the oblique movements of the eyeball are by no means due to the action of the superior and inferior oblique muscles acting alone, but that in every such movement there is a coördination of two of the recti muscles with one of the obliques. Thus, in rotations which direct the pupil upward and inward the superior and internal recti coöperate with the inferior oblique, and in the downward and outward movements the inferior and external recti coöperate with the superior oblique.

Fig. 518.

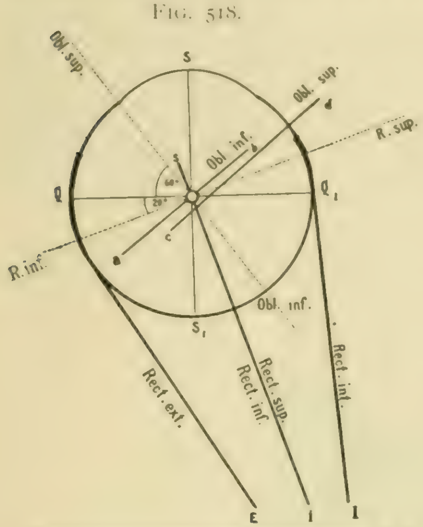


Diagram showing action of ocular muscles. S, S_1, Q, Q_1, sagittal and transverse axes of eyeball; direction of pull of muscles is indicated by lines; dotted lines indicate axes around which superior and inferior recti and oblique muscles rotate eyeball; vertical axis (O) corresponds to axis of rotation of internal and external recti. (*Landois.*)

A purely outward or inward rotation can be produced by the action of the external or internal rectus, as the case may be. But it is to be noted that the movements of the eyeball are always bilateral, and that the inward rotation of the one eye is generally associated with the outward rotation of the other, the combined movements thus requiring the coöperation of different muscles.

In all movements of the eyeballs there is, accordingly, a coördination of various orbital muscles, and when the combined oblique movements are performed this coördination becomes somewhat complicated. The direction of both pupils upward and to the right requires the coördination in the right eye of the inferior oblique and the superior and external recti and in the left eye of the inferior oblique and the superior and internal recti.

Variations.—But few variations have been observed in the orbital muscles. Absence of the levator palpebræ superioris has been noted, and a slip from this muscle, termed the *tensor trochleæ*, sometimes passes to the trochlea.

II. THE HYPOGLOSSAL MUSCLES.

1. Genio-glossus.
2. Hyo-glossus.
3. Stylo-glossus.
4. Lingualis.

It is well known that the hypoglossal nerve represents the anterior roots of three spinal nerves which have secondarily been taken up into and consolidated with the cranial region. Corresponding to these three nerves are three myotomes which combine to give rise to muscles connected with the tongue.

1. Genio-Glossus (Fig. 1339).

The genio-glossus is described with the tongue (page 1578).

2. Hyo-Glossus (Fig. 1339).

The hyo-glossus is described with the tongue (page 1578).

Variations.—The fibres which arise from the lesser cornu of the hyoid bone are frequently separate from the rest of the muscle and have been described as the *chondro-glossus*, and the fibres arising from the body of the hyoid are frequently separated by a distinct interval from those arising from the greater cornu, the former constituting a muscle which has been termed the *basio-glossus* and the latter the *cerato-glossus*. A bundle of fibres, forming what has been termed the *triticeo-glossus*, sometimes arises from the cartilago triticea, situated in the lateral hyo-thyroid ligament, and passes upward and forward to insert along with the posterior fibres of the hyo-glossus.

3. Stylo-Glossus (Fig. 1339).

The stylo-glossus is described with the tongue (page 1579).

Variations.—The stylo-glossus is occasionally absent, and may in such cases be replaced by a *mylo-glossus*, which arises from the inner surface of the angle of the mandible or from the stylo-mandibular ligament and is inserted into the sides and under surface of the tongue. This muscle is usually present in the form of some small bundles of fibres having the attachments described.

4. Lingualis (Fig. 1340).

The lingualis is described with the tongue (page 1579).

III. THE TRUNK MUSCLES.

THE DORSAL MUSCLES.

In employing the term dorsal to indicate a group of muscles it must be clearly understood that the group does not include all the muscles which, in the adult condition, are found upon the dorsal surface of the body. The term, so far as it has a topographic significance, refers to a phylogenetic stage in which the muscles it is intended to designate were the only dorsal muscles, and, as here employed, it indicates only those muscles which are derived from the dorsal portions of the embryonic myotomes and are supplied by the posterior divisions (dorsal rami) of the spinal nerves.

An examination of the muscles of the back readily shows that they consist of two distinct sets. There is a *superficial set*, consisting of broad and flat muscles, which are, with few exceptions, attached to the skeleton of the fore-limb, and a *deeper set*, consisting of elongated and relatively thick muscles, whose attachments are confined to portions of the axial skeleton. The muscles of the former set, which may conveniently be designated the *spino-humeral muscles*, are all supplied by branches from the ventral rami of the spinal nerves; they have reached their present position, in which they almost completely cover in the true dorsal muscles, by a secondary migration from the more ventral portions of the trunk, and properly belong to the system of limb muscles, in connection with which they will be described.

The true axial dorsal muscles are all included in the deeper set. Viewed from the surface, they appear to form elongated columns of muscle-tissue, extending continuously, more or less parallel with the spinal column, over considerable stretches of the back; but when the more superficial portions of the columns are removed, it will be seen that the deeper portions are associated with the individual vertebræ, their fibres possessing a more or less distinct segmental arrangement. The columns, indeed, are to be regarded as formed by the fusion of a number of originally independent muscle-segments, derived from the dorsal portions of a corresponding number of myotomes, a mode of formation also indicated by the fact that the columns are supplied by nerves from a greater or less number of successive spinal nerves, from just as many, indeed, as there are myotomes entering into their composition.

Comparative anatomy demonstrates that the dorsal musculature may, furthermore, be regarded as consisting of two parallel portions or tracts, a median and a lateral. The former portion, which includes the majority of the dorsal muscles, is composed of those muscles which fundamentally arise from the transverse processes of the vertebræ and are inserted into the spinous processes, and may therefore be termed the *transverso-spinal* portion; while the more lateral tract consists of muscles which, taking their origin primarily from the transverse processes, are inserted into the ribs or their homologues, and may accordingly be termed the *transverso-costal* portion. A certain amount of overlapping of the median tract by the lateral one occurs in man; indeed, in the lumbar region the two tracts fuse to a certain extent to form the sacro-spinalis; but throughout the thoracic and cervical regions they are fairly distinct.

The **deep fascia of the back** invests all the muscles of the dorsal group, separating them from the spino-humeral group. Above, the fascia is not especially strong, and in the cervical and upper thoracic regions forms what is termed the **fascia nuchæ**, which lies beneath the trapezius and rhomboid muscles. In the lower thoracic and lumbar regions, however, the fascia becomes considerably thickened, especially that portion which invests the sacro-spinalis (*vertebral aponeurosis*), forming a strong rhomboidal sheet extending from about the level of the sixth thoracic vertebra to the tip of the sacrum, its anterior borders giving attachment to various muscles, while the posterior ones are attached to the posterior portions of the iliac crests, where it becomes continuous with the fascia lata covering the gluteal muscles.

FIG. 519.

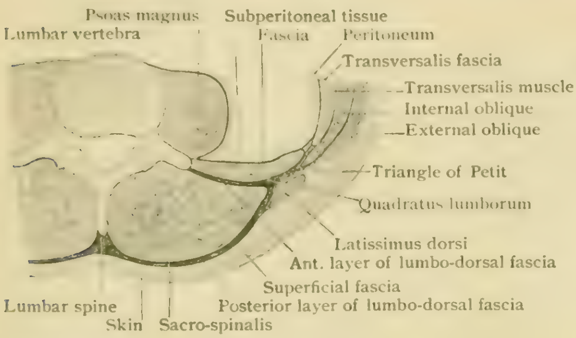


Diagram showing formation and relations of lumbo-dorsal fascia to muscles of body-wall.

This dense layer is termed the **fascia lumbo-dorsalis** (Fig. 559), and is generally regarded as consisting of two lateral portions which are practically united in the mid-dorsal line by their common attachment to the spinous processes of the vertebræ and the supraspinous ligaments. Each of these lateral portions is again considered as consisting of two layers which together invest the sacro-spinalis (Fig. 519), the *posterior layer* being that which has already been described, while the *anterior layer* is attached medially to the tips of the transverse processes of the lumbar vertebræ, above to the lower border of the twelfth rib, and below to the crest of the ilium. It passes outward beneath the sacro-spinalis, separating it from the quadratus lumborum, and at the outer border of the former muscle it fuses with the posterior layer to form a strong aponeurotic band, from which the latissimus dorsi and the internal oblique and transverse abdominal muscles take partial origin, and which is continued ventrally over the inner surface of the transversus abdominis as the *fascia transversalis.*

(*a*) THE TRANSVERSO-COSTAL TRACT.

1. Sacro-spinalis.
2. Ilio-costalis.
3. Longissimus.
4. Splenius.

1. SACRO-SPINALIS (Fig. 520).

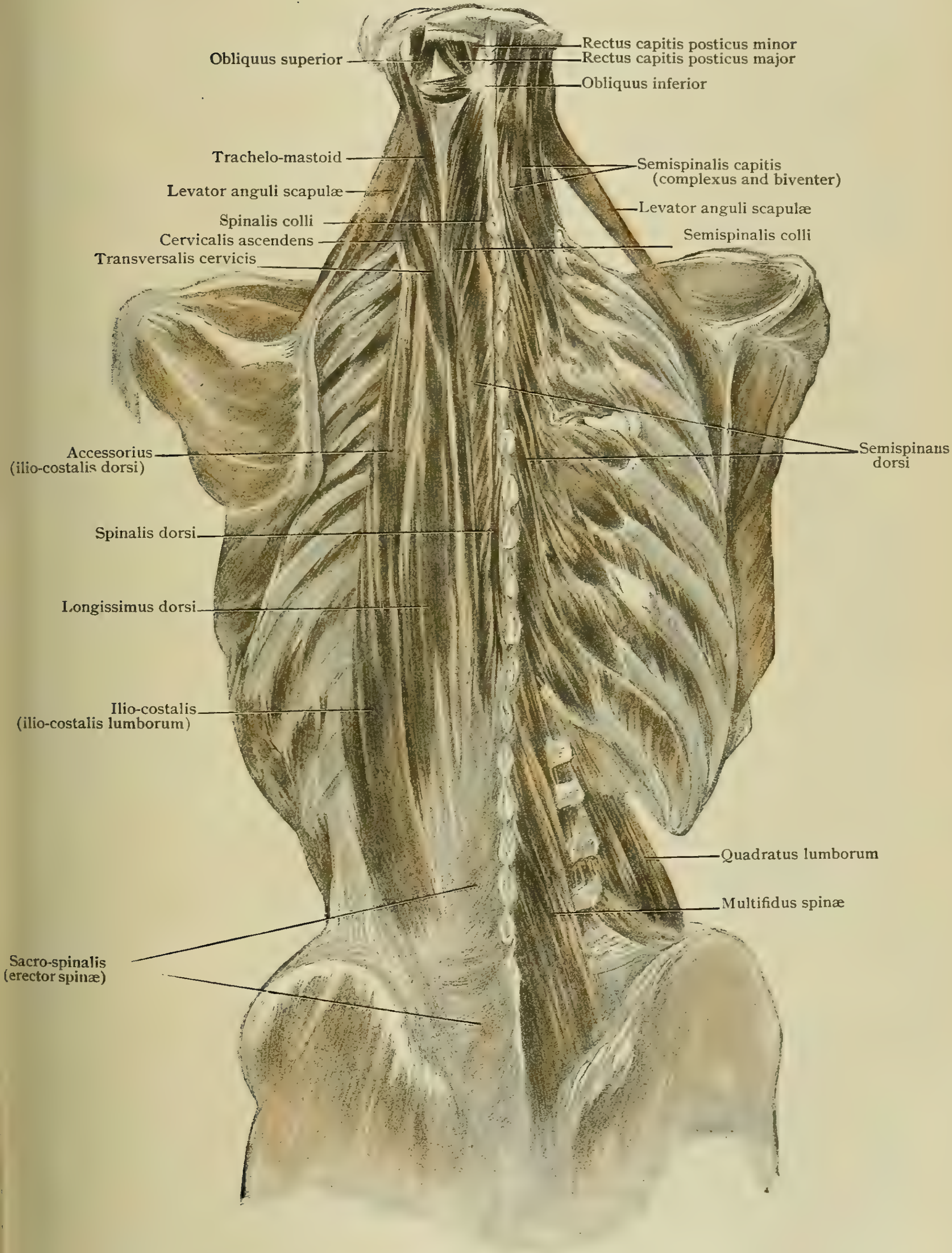
Attachments.—The sacro-spinalis, sometimes termed the *erector spinæ*, forms a large muscular mass occupying the lumbar portion of the vertebral groove. It takes its *origin* from the under surface of the lumbo-dorsal fascia, the crest of the ilium, the posterior surface of the sacrum, and the spines of the lumbar vertebræ. Anteriorly it divides into three separate muscles, two of which, the ilio-costalis and the longissimus, belong to the transverso-costal group, while the third, the spinalis, is a member of the transverso-spinal series.

Nerve-Supply.—The posterior divisions of the lumbar nerves.

2. ILIO-COSTALIS (Fig. 520).

Attachments.—The ilio-costalis, also termed the *sacro-lumbalis*, is the most lateral of the three muscles into which the sacro-spinalis divides, and is the forward continuation of the portion of that muscle which arises from the crest of the ilium. The muscle is continued upward in the vertebral groove immediately internal to the angles of the ribs as far as the fourth cervical vertebra, receiving, however, accessions from the ribs as it passes over them. The fibres which *arise* from the iliac

FIG. 520.



Dissection of muscles of back, showing transverso-costal and transverso-spinal tracts.

crest are mainly *inserted* into the lower six or seven ribs, and form what is termed the **ilio-costalis lumborum.** With the remainder of the iliac fibres bundles *arising* from the lower five, six, or seven ribs associate themselves to form the **ilio-costalis dorsi,** also termed the *accessorius*, which *inserts* into the upper five or six ribs ; and, finally, the uppermost portion of the muscle, the **ilio-costalis cervicis** or *cervicalis ascendens*, is formed by the union of bundles *arising* from the upper six or seven ribs, and is *inserted* into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebræ.

Nerve-Supply.—From the posterior divisions of the spinal nerves from the lower cervical to the first lumbar.

Action.—The various portions of the ilio-costalis tend to bend the spinal column backward in the lower cervical, thoracic, and lumbar regions, and also to draw it somewhat to one side. They may likewise have some action in drawing down the ribs, assisting in forced expiration.

3. Longissimus (Fig. 520).

Attachments.—The longissimus represents the upward prolongation of that portion of the sacro-spinalis which *arises* from the dorso-lumbar fascia and the lumbar vertebræ. It is continued upward immediately medial to the ilio-costalis to be *inserted* into the mastoid process of the temporal bone, but, like the ilio-costalis, it receives in its course accessory bundles and also gives off bundles which are inserted into the skeletal parts over which it passes.

The fibres which represent the direct continuation of the sacro-spinalis are continued as far upward as the first thoracic vertebra, and are reinforced by short accessory bundles from the transverse processes of the lower six thoracic vertebræ to form what is termed the **longissimus dorsi.** The fibres of this portion of the muscle are *inserted* along two lines, the medial of which passes along the accessory processes of the lumbar vertebræ and the transverse processes of all the thoracic vertebræ, while the lateral line passes along the transverse processes of the lumbar vertebræ and the angles of the ribs as far forward as the second. From the transverse processes of the upper six thoracic vertebræ bundles *arise* which unite to form the **longissimus cervicis** or *transversalis cervicis*, which continues the line of the longissimus to an *insertion* into the posterior tubercles of the transverse processes of the second to the sixth cervical vertebræ ; and, finally, the **longissimus capitis** or *trachelo-mastoid* is formed by bundles *arising* from the transverse processes of the three upper thoracic vertebræ and the articular processes of the three lower cervical, and passes upward to be *inserted* into the mastoid process of the temporal bone.

Nerve-Supply.—From the posterior divisions of the spinal nerves from the third cervical to the second sacral.

Action.—The thoracic and cervical portions of the longissimus will draw the spinal column backward and to one side ; the longissimus capitis will have a similar action on the head.

4. Splenius (Fig. 520).

Attachments.—The splenius forms a flat muscle which *arises* from the spinous processes of the upper four or six thoracic and the seventh cervical vertebræ and from the lower half of the ligamentum nuchæ. It passes upward and slightly laterally and divides into two portions, the lower of which, curving around the outer edge of the upper portion, passes to an *insertion* in the posterior tubercles of the upper three cervical vertebræ, forming the *splenius cervicis.* The upper portion, which is termed the *splenius capitis*, continues upward, and is *inserted* by a short tendon into the posterior border of the mastoid process of the temporal bone and into the outer part of the superior nuchal line.

Nerve-Supply.—From the posterior divisions of the second to the eighth cervical nerves.

Action.—The splenius cervicis will draw the upper cervical vertebræ backward and will rotate the atlas towards the side of the muscle in action. The action of

the splenius capitis upon the head will be similar ; the simultaneous action of the two muscles of opposite sides will bend the head backward, each muscle neutralizing the rotatory effect of the other.

(*b*) THE TRANSVERSO-SPINAL TRACT.

1. Spinalis.	6. Intertransversales.
2. Semispinalis.	7. Rectus capitis posticus major.
3. Multifidus.	8. Rectus capitis posticus minor.
4. Rotatores.	9. Obliquus capitis superior.
5. Interspinales.	10. Obliquus capitis inferior.

1. Spinalis (Fig. 520).

Attachments.—The spinalis in its lower portion is the continuation of the deeper and innermost fibres of the sacro-spinalis, and, like the longissimus, with which it is partly associated, it is regarded as consisting of a thoracic, a cervical, and a cranial portion. The **spinalis dorsi** *arises* from the spinous processes of the upper two lumbar and the lower two or three thoracic vertebræ by tendons common to it and the longissimus dorsi. It forms a thin, flat muscle which passes upward, *inserting* as it goes into the spinous processes of the thoracic vertebræ from the second to the eighth or ninth, but one vertebra intervening between its uppermost tendon of origin and its lowermost tendon of insertion. The **spinalis cervicis** *arises* from the spinous processes of the upper two or four thoracic and the lower two cervical vertebræ, and ascends alongside the spinous processes of the cervical vertebræ to be *inserted* into those of the second, third, and fourth vertebræ. The **spinalis capitis** consists of bundles *arising* from the spinous processes of the upper thoracic and last cervical vertebræ, and passes upward to be *inserted* with the semispinalis capitis.

Nerve-Supply.—From the posterior divisions of the spinal nerves from the third cervical to the last thoracic.

Action.—To extend the spinal column.

2. Semispinalis (Fig. 520).

Attachments.—The semispinalis forms the *superficial layer* of the muscles lying in the groove between the spinous and transverse processes of the vertebræ. Three portions may be recognized in it. The **semispinalis dorsi** *arises* from the transverse processes of the lower six or seven thoracic vertebræ ; its fibres are directed obliquely upward and medially and are *inserted* into the spinous processes of the five or six upper thoracic and last two cervical vertebræ. The **semispinalis cervicis** *arises* from the transverse processes of the five or six upper thoracic vertebræ and is *inserted* into the spinous processes of the second, third, fourth, fifth, and sometimes the sixth cervical vertebræ. This portion of the muscle is almost concealed beneath the uppermost portion, the **semispinalis capitis**, which *arises* from the transverse processes of the upper six thoracic vertebræ and the articular and transverse processes of the lower three or four cervical vertebræ. The fibres are directed almost vertically upward, and are joined by the spinalis capitis to form a broad muscle-sheet which is *inserted* into the under surface of the squamous portion of the occipital bone between the superior and inferior nuchal lines.

An intermediate tendinous intersection usually divides the semispinalis capitis into an upper and a lower portion, and is much more distinct in the more medial bundles than in the lateral ones. Frequently these more medial bundles are separated somewhat from the others, and they have been considered a distinct muscle and termed the *biventer*, the lateral portion of the muscle being named the *complexus*.

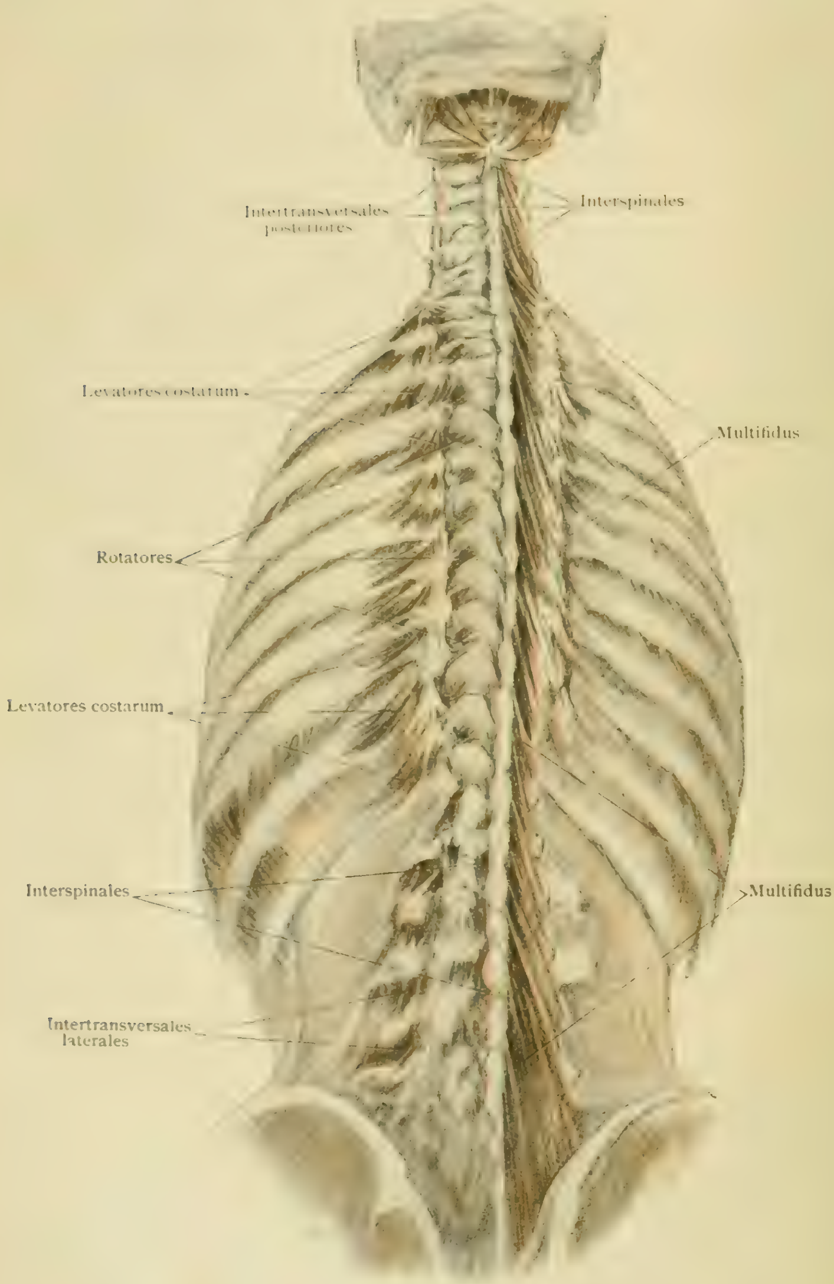
Nerve-Supply.—From the posterior divisions of the spinal nerves from the second cervical to the last thoracic.

Action.—The semispinalis dorsi and cervicis extend the vertebral column and rotate it somewhat towards the opposite side. The semispinalis capitis draws the head backward and also rotates it slightly towards the opposite side.

3. Multifidus (Figs. 520, 521).

Attachments.—The multifidus (*multifidus spinæ*) constitutes the ***middle layer*** of the muscles occupying the groove between the transverse and spinous processes

Fig. 521.



Deep muscles of back.

of the vertebræ, and is covered, in the thoracic and cervical regions, by the semispinalis. It takes its *origin* from the dorsal surface of the sacrum and from the trans-

verse or articulating processes of all the vertebræ as far up as the fourth cervical. The fibres from each vertebra pass over from two to four of the succeeding vertebræ and are *inserted* into the spinous processes of the third to the fifth, the entire insertion of the muscle extending from the spinous process of the last lumbar vertebra to that of the axis.

Nerve-Supply.—From the posterior divisions of the spinal nerves from the third cervical to the last lumbar.

Action.—To bend the spinal column backward and rotate it towards the opposite side.

4. Rotatores (Fig. 521).

Attachments.—The **rotatores** (*rotatores dorsi*) form the *deepest layer* of the muscles occupying the spino-transverse groove. They form a series of small muscles hardly distinguishable from the bundles of the multifidus, beneath which they lie. They are to be found along the entire length of the spinal column from the sacrum to the axis, *arising* from the transverse process of one vertebra and passing, some of the fibres to the base of the spinous process of the next succeeding vertebra (*rotatores breves*) and the rest to a corresponding point of the second vertebra above (*rotatores longi*).

Nerve-Supply.—From the posterior divisions of the spinal nerves from the third cervical to the last lumbar.

Action.—To bend the spinal column backward and rotate it towards the opposite side.

5. Interspinales (Fig. 521).

Attachments.—The interspinales are relatively small muscles which pass between the spinous processes of succeeding vertebræ. They are usually absent throughout the greater portion of the thoracic region, occurring only in connection with the first and the last two spines, but they are exceptionally well developed in the lumbar region and are usually paired in the cervical region, where they stop at the axis.

Nerve-Supply.—From the posterior divisions of the spinal nerves from the third cervical to the fifth lumbar.

Action.—Acting together to bend the cervical and lumbar portions of the spinal column backward.

6. Intertransversales (Fig. 521).

Attachments.—The name intertransversales (**mm. intertransversarii**) has been applied to a series of small muscles occurring in the cervical and lumbar regions and extending between the transverse or mammillary processes of successive vertebræ. In each of the regions named two sets of intertransversales are recognized, but it seems probable that only one of the sets in such region belongs to the dorsal group of muscles. This set will alone be considered here, the other (anterior) one being described with the ventral muscles of the regions in which it occurs.

The **intertransversarii posteriores** occur only in the cervical region and extend between the posterior tubercles of the transverse processes of succeeding vertebræ. The **intertransversarii mediales** occur only in the lumbar region and extend between the mammillary processes of successive vertebræ.

Nerve-Supply.—Probably by fibres belonging to the posterior divisions of the cervical and lumbar nerves, but it is at present insufficiently determined.

Action.—To bend the cervical and lumbar portions of the vertebral column laterally.

7. Rectus Capitis Posticus Major (Fig. 522).

Attachments.—The greater straight muscle (**m. rectus capitis posterior major**) *arises* from the apex of the spinous process of the axis and passes upward and outward, broadening as it goes, to be *inserted* into the middle portion of the inferior nuchal line.

Nerve-Supply.—By a branch from the posterior division of the suboccipital nerve.

Action.—To draw the head backward and to rotate it towards the same side.

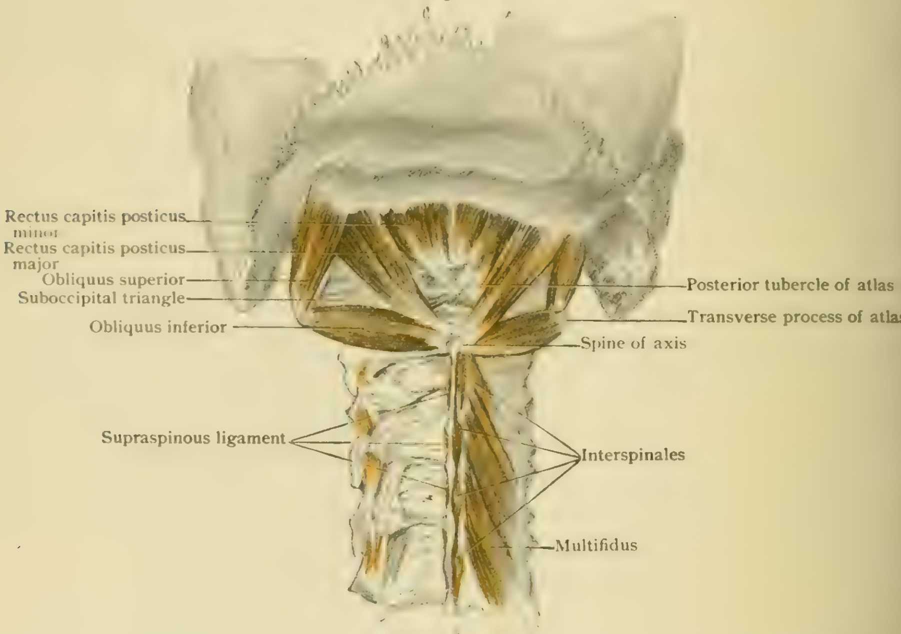
8. Rectus Capitis Posticus Minor (Fig. 522).

Attachments.—The lesser straight muscle (**m. rectus capitis posterior minor**) *arises* from the posterior tubercle of the atlas and passes upward, broadening as it goes, to be *inserted* into the inner portion of the inferior nuchal line.

Nerve-Supply.—By a branch from the posterior division of the suboccipital nerve.

Action.—To draw the head backward.

Fig. 522.



Deep dissection of neck, showing suboccipital group of muscles.

9. Obliquus Capitis Superior (Fig. 522).

Attachments.—The superior oblique muscle of the head *arises* from the transverse process of the atlas and passes upward to be *inserted* into the squamous portion of the occipital immediately above the outer part of the inferior nuchal line.

Nerve-Supply.—By a branch from the posterior division of the suboccipital nerve.

Action.—To draw the head backward and slightly laterally.

10. Obliquus Capitis Inferior (Fig. 522).

Attachments.—The inferior oblique muscle of the head *arises* from the tip of the spinous process of the axis and is directed outward and upward to be *inserted* into the transverse process of the atlas.

Nerve-Supply.—By a branch from the posterior division of the suboccipital nerve.

Action.—To rotate the axis towards the same side.

The Sacro-Coccygeus Posterior.—The reduction of the caudal vertebræ in man, indicated by the condition of the coccygeal vertebræ, has brought about a reduction of the terminal portion of the dorsal axial musculature, it being, as a rule, represented only by the ligaments upon the dorsal surface of the coccyx. Quite frequently, however, muscular fibres occur intermingled with the connective tissue, and occasionally a distinct muscle, the sacro-coccygeus posterior, may be found, extending from the last sacral vertebra or even from the greater sacro-sciatic ligament to the coccyx.

THE VENTRAL MUSCLES.

The ventral trunk musculature includes all those axial muscles which are supplied from the anterior divisions (ventral rami) of the spinal nerves. As already indicated (page 473), it is divisible into three subgroups : a group of more median muscles, characterized by their fibres retaining more or less perfectly a longitudinal direction and constituting the *rectus group ;* a more lateral group, in which the fibres possess a distinctly oblique or transverse direction, and may consequently be termed the *obliquus group ;* and, finally, a *hyposkeletal group*, whose fibres have a longitudinal direction, and which is situated anterior or ventral to the spinal column.

Instead of considering the various muscles belonging to each of these groups in succession, it seems more convenient to combine a topographic classification with the morphological one, and to describe the various groups as they occur in the neck, thoracic, abdominal, and perineal regions. It must be understood, however, that the delimitations of these regions are somewhat arbitrarily chosen, and that there is, so far as the muscles are concerned, a considerable amount of overlapping of certain regions, portions of myotomes which strictly belong to the thoracic region, for instance, being found within the limits of what is recognized as the abdominal region. In many cases these overlapping myotomes have united with myotomes of the lower region to form a continuous muscle, and it is consequently impossible to refer them to their proper topographic position without doing violence to the individuality of the muscles which they help to form ; but when they remain practically distinct from the muscles of their adopted region, they will be referred to the region from which they have come.

It will be convenient to consider first the muscles of the abdominal region, thereafter taking up in succession those of the thoracic and cervical regions, those of the perineal region being left until the last.

THE ABDOMINAL MUSCLES.

The Superficial Fascia of the Abdomen.—The superficial fascia of the abdomen is usually described as consisting of two layers. These, however, are well marked only over the anterior and especially the lower part of the abdominal wall, losing their distinctness laterally and above, where they pass over into the superficial fasciæ of the back and thorax. The superficial layer (*Camper's fascia*) usually contains a considerable amount of fat, except at the umbilicus, and may occasionally reach a great thickness owing to the development of that tissue. The deeper layer immediately underlies the fatty layer, and is a connective-tissue membrane of varying density, containing a considerable amount of yellow elastic tissue. It is connected to the deep abdominal fascia which covers the muscles of the abdominal wall by loose areolar tissue, except along the median line, where it is firmly adherent along the linea alba and around the umbilicus. A short distance above the symphysis pubis it gives off a band which is largely composed of elastic tissue and is inserted below into the fascia of the penis, forming the suspensory ligament of that organ (Fig. 528).

In the inguinal region the deep layer of the superficial fascia is especially well defined, forming what has been termed the *fascia of Scarpa.* Laterally it passes down over Poupart's ligament to unite with the fascia lata of the thigh, the superficial vessels and lymph-nodes of this region lying between it and the superficial layer. More medially it is continued down over the spermatic cord, becoming continuous below partly with the deep layer of the superficial fascia of the perineum (*fascia of Colles*) and partly, after fusing with the superficial layer, which loses its fat, with the dartos of the scrotum.

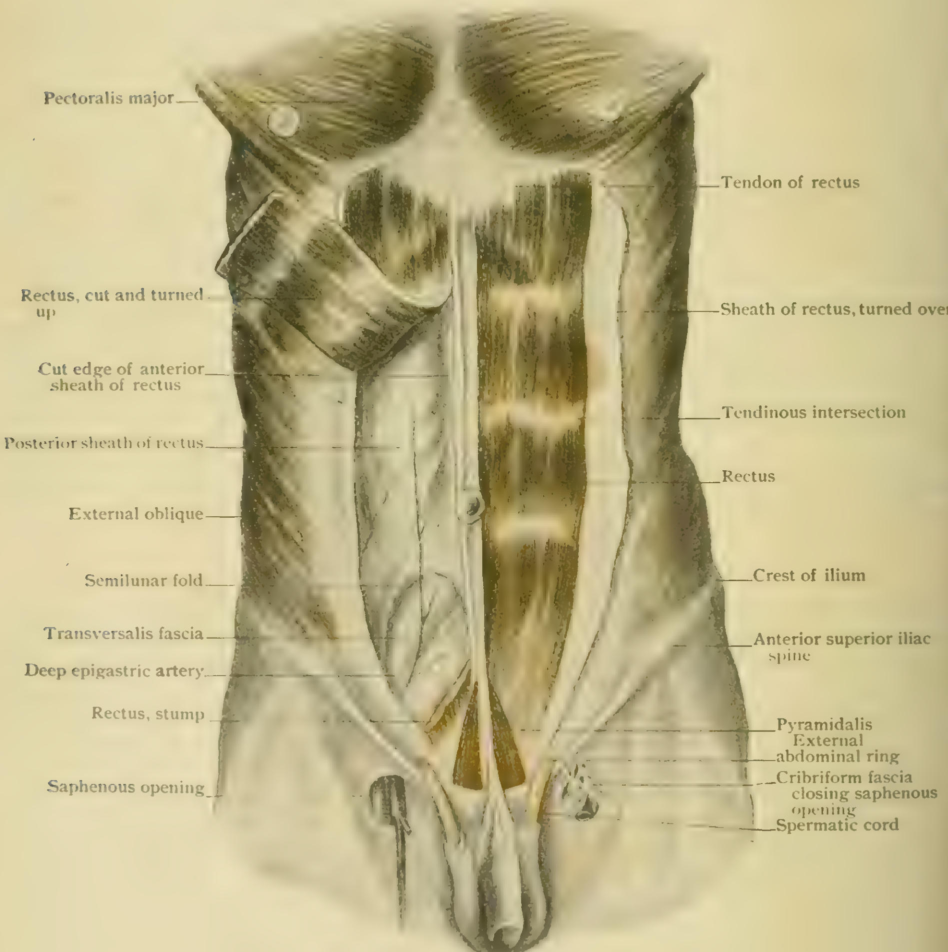
(*a*) THE RECTUS MUSCLES.

1. Rectus abdominis. 2. Pyramidalis.

1. Rectus Abdominis (Fig. 523).

Attachments.—The rectus abdominis forms a flat but strong muscle which traverses the entire length of the ventral abdominal wall immediately lateral to the linea alba. It *arises* from the anterior surface of the xiphoid process of the sternum and from the cartilages of the fifth, sixth, and seventh ribs, and is *inserted* by a strong tendon into the crest and symphysis of the pubis.

Fig. 523.



Muscles of anterior abdominal wall.

The fibres are directed longitudinally, and are interrupted along three and occasionally four transverse lines by tendinous intersections of the muscle. One of these *inscriptiones tendineæ* occurs about the level of the umbilicus, another, often affecting only the medial portion of the muscle, corresponds approximately to the lower margin of the thorax, and the third lies about midway between the two. The fourth, when present, frequently is limited to the lateral portion of the muscle, and occurs about midway between the level of the umbilicus and the crest of the pubis.

Nerve-Supply.—From the anterior divisions of the thoracic nerves from the fifth to the twelfth.

Action.—The recti act as flexors of the thorax upon the pelvis or, acting from above, they flex the pelvis on the thorax. They also aid in the compression of the abdominal viscera in defecation and parturition and in strong expiratory efforts.

Variations.—The origin of the rectus sometimes ascends to the fourth or third rib or even higher. The tendinous inscriptions are probably the persistent representatives of the connective-tissue partitions between certain of the myotomes of which the muscle is composed. They are subject to a certain amount of variation in number, five or six occasionally occurring, while, on the other hand, they may be reduced to two.

2. Pyramidalis (Fig. 523).

Attachments.—The pyramidalis is a somewhat variable muscle which *arises* below from the upper surface of the body of the pubis and from the symphysis and is *inserted* above into the linea alba, somewhere between the umbilicus and the symphysis.

Nerve-Supply.—From the anterior divisions of the eleventh and twelfth thoracic nerves.

Action.—To tense the linea alba.

Variations.—The extent to which the muscle is developed varies greatly, its insertion sometimes extending well up towards the umbilicus, while, on the other hand, it is not infrequently absent. This latter condition has been estimated to occur in over 16 per cent. of cases.

(*b*) THE OBLIQUUS MUSCLES.

1. Obliquus externus.
2. Obliquus internus.
3. Cremaster.
4. Transversalis.
5. Quadratus lumborum.
6. Intertransversales laterales.

1. Obliquus Externus (Fig. 524).

Attachments.—The external oblique forms a muscular sheet in the lateral portions of the anterior abdominal wall. It *arises* by seven or eight fleshy digitations from the corresponding number of lower ribs, the upper digitations alternating with digitations of the serratus magnus, while the lower three alternate with those of the latissimus dorsi. The fibres from the lowest ribs pass vertically downward to be *inserted* into the crest of the ilium ; the remainder are directed mainly downward and forward and, above, directly forward to join a broad aponeurotic sheet which contributes to the formation of the ventral abdominal aponeurosis.

Nerve-Supply.—From the anterior divisions of the eighth to the twelfth thoracic nerves and from the ilio-hypogastric and ilio-inguinal nerves.

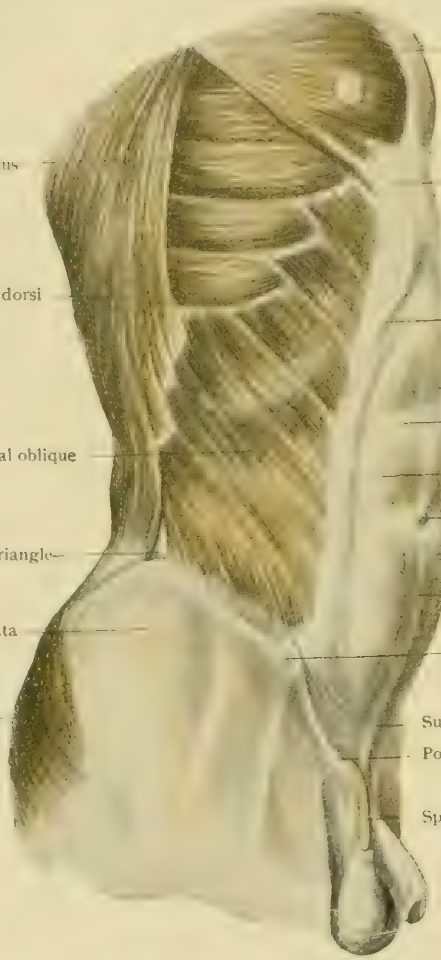
Action.—Since the external oblique is a curved sheet which passes from the lateral portions of the abdominal wall towards the mid-ventral line, contraction of its fibres will tend to compress the abdominal contents and so assist in micturition, defecation, parturition, and expiration, its action in the last-named process being increased by the power which it possesses of drawing the lower ribs downward. Furthermore, according as it acts from below or above, it will flex the thorax and spinal column upon the pelvis or the pelvis upon the spinal column, at the same time producing a slight rotation of the thorax to the opposite side and the pelvis to the same side. When the two muscles of opposite sides act together, the rotatory action of each will be neutralized. By the most lateral fibres a lateral flexion of the thorax or pelvis will be produced.

2. Obliquus Internus (Fig. 525).

Attachments.—The internal oblique muscle lies immediately beneath the external one. It *arises* from the outer half of Poupart's ligament, from the whole length of the middle lip of the crest of the ilium, and from the lumbo-dorsal fascia. From this extended origin its fibres spread out in a fan-shaped manner, the more posterior ones passing upward and slightly forward to be *inserted* into the

lower three ribs, while of the rest the more anterior ones pass forward and upward, those from the neighborhood of the anterior superior iliac spine directly forward, and those from Poupart's ligament forward and downward, all joining in a flat aponeurosis which unites with the anterior abdominal aponeurosis at the linea semilunaris. In its lowermost portion the aponeurosis unites with that of the transversalis to form what is termed the *conjoined tendon*, and by this it is attached to the crest of the pubis.

FIG. 524.



Dissection of lateral body-wall, showing external oblique and adjoining muscles.

Nerve-Supply.—From the anterior divisions of the eighth to the twelfth thoracic nerves and from the ilio-hypogastric and ilio-inguinal nerves.

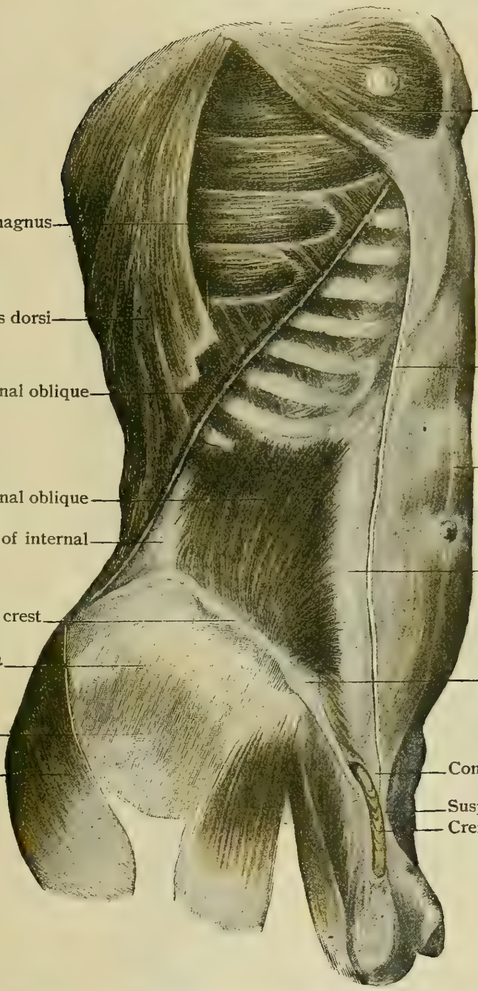
Action.—The internal oblique acts very similarly to the external in compressing the abdominal contents, in drawing the lower ribs downward, and in flexing the thorax or pelvis laterally. It will also flex the thorax and vertebral column upon the pelvis or the pelvis upon the vertebral column, but in these actions the accompanying rotation will be in a direction contrary to that caused by the external oblique, the thorax being rotated to the same side and the pelvis to the opposite side. It may be remarked that the rotatory action of the external oblique of the one side and the internal oblique of the other will be in the same direction.

Variations.—The internal oblique may be crossed by one or more tendinous intersections which have probably the same significance as those of the rectus abdominis.

3. Cremaster (Figs. 525, 1671).

Attachments.—The cremaster muscle consists of a series of somewhat scattered loops of muscle-tissue derived from the lower part of the internal oblique and to a slight extent from the transversalis. It is attached laterally to Poupart's ligament and medially to the anterior layer of the sheath of the rectus. The loops descend through the inguinal canal along with the spermatic cord, the muscle being

Fig. 525.



Dissection of lateral body-wall, showing internal oblique muscle.

well developed only in the male, and spread out in the tunica vaginalis communis of the testis and spermatic cord. The loops are united by connective tissue which forms part of the cremasteric fascia.

Nerve-Supply.—By the genital branch of the genito-crural nerve.

Action.—To draw the testis upward towards the external abdominal ring.

4. Transversalis (Fig. 526).

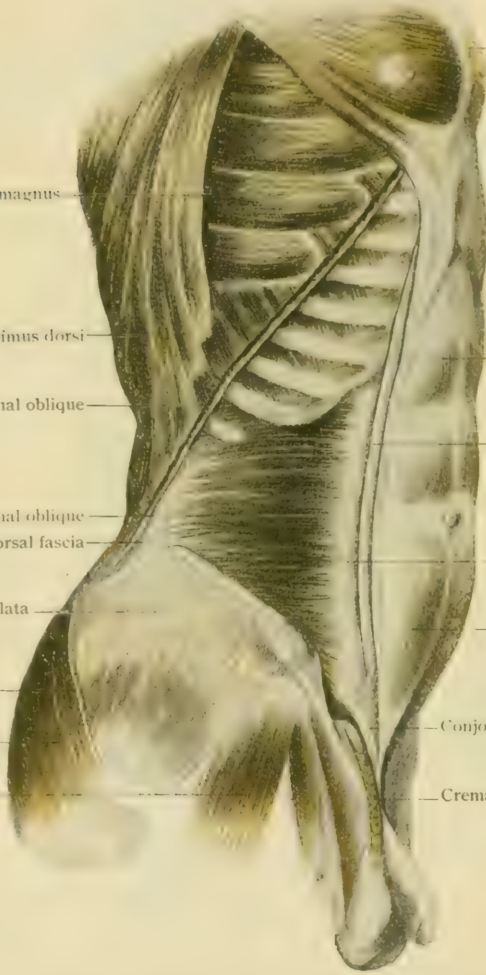
Attachments.—The transversalis (**m. transversus abdominis**) is the deepest layer of muscle on the lateral abdominal wall and immediately underlies the internal oblique. It *arises* from the cartilages of the lower six ribs, from the lumbo-dorsal

fascia, the inner lip of the crest of the ilium, and the outer one-third of Poupart's ligament. Its fibres pass horizontally inward to join the ventral abdominal aponeurosis along the linea semilunaris; the lower ones, however, bending somewhat downward, pass into an aponeurosis which unites with that of the internal oblique to form the conjoined tendon attached to the crest of the pubis.

Nerve-Supply.—From the anterior divisions of the seventh to the twelfth thoracic nerves and from the ilio-hypogastric and ilio-inguinal nerves.

Action.—To compress the contents of the abdomen.

FIG. 526.



Dissection of lateral body-wall, showing transversalis muscle.

The **fascia transversalis** is a thin layer of connective tissue which lines the inner (deeper) surface of the transversalis muscle. Posteriorly it is continuous with the strong aponeurotic band formed by the fusion of the superficial and deep layers of the lumbo-dorsal fascia, anteriorly it combines with the deeper layer of the ventral abdominal aponeurosis to form the posterior layer of the sheath of the rectus muscle, and above it unites with the fascia covering the lower surface of the diaphragm. Below its lateral portion is attached to the crest of the ilium and the outer part of Poupart's ligament where it becomes continuous with the iliac fascia, but more medially it is continued downward beneath Poupart's ligament to form the anterior wall of the sheath of the femoral vessels, the portion of it immediately above the vessels being

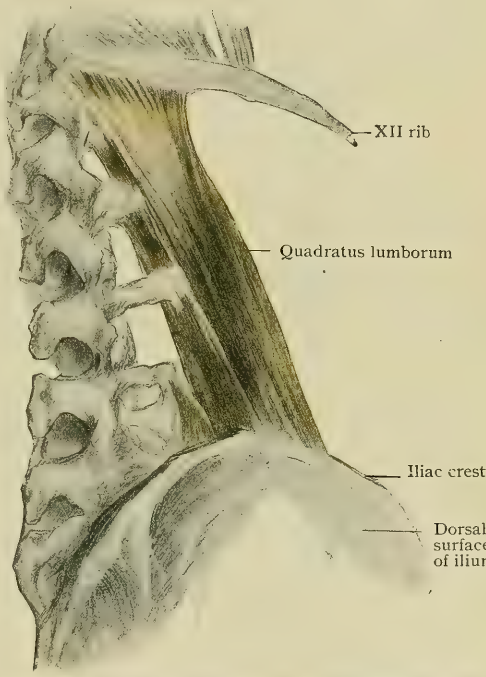
thickened somewhat to form the *deep crural arch* (Fig. 1496). More medially still it is attached to the free edge of Gimbernat's ligament and to the upper surface of the superior ramus and body of the pubis.

A little over 1 cm. above Poupart's ligament, and about half-way between the anterior superior iliac spine and the symphysis pubis, the transversalis fascia is perforated by the spermatic cord in the male and by the ligamentum teres of the uterus in the female. The fascia is continued downward and forward over the cord or ligament to form a somewhat funnel-like investment for it termed the *infundibuliform fascia*, the inner margin of the funnel marking the position of the internal abdominal ring.

5. Quadratus Lumborum (Fig. 527).

Attachments.—The quadratus lumborum is a flat quadrilateral muscle which lies towards the back part of the abdominal wall, extending between the crest of the ilium and the lower border of the twelfth rib. It consists of two layers of fibres which frequently are distinguishable from each other only with difficulty. The *anterior layer*, which *arises* from the transverse processes of the lower four lumbar vertebræ and from the posterior part of the iliac crest, is *inserted* into the lower border of the twelfth rib; the *posterior layer* (Fig. 527) *arises* from the crest of the ilium and is *inserted* into the lower border of the twelfth rib and into the transverse processes of the upper four lumbar vertebræ.

Fig. 527.



Quadratus lumborum muscle of right side, seen from behind.

Nerve-Supply.—By branches from the lumbar plexus.

Action.—To draw downward the last rib and to bend the lumbar portion of the spinal column laterally.

Relations.—The quadratus lumborum rests behind upon the deep layer of the fascia lumbo-dorsalis (Fig. 519), which separates it from the spinosacral muscle. Its anterior surface is in relation to the kidney and the ascending or descending colon, is crossed by the lumbar arteries, and is covered towards its inner margin by the psoas major.

6. Intertransversales Laterales (Fig. 521).

Attachments.—The lateral intertransversales are a series of small quadrilateral muscles which extend between successive transverse processes of the lumbar vertebræ.

Nerve-Supply.—Probably from the anterior rami of the lumbar nerves.

Action.—To bend laterally the lumbar portion of the spinal column.

The Ventral Abdominal Aponeurosis (Fig. 528).—The broad aponeurotic sheets into which the oblique and transverse muscles of the abdomen are continued at their anterior (medial) edges unite more or less intimately with one another and with the fascia transversalis to form the *ventral abdominal aponeurosis*. Laterally the various layers of which this aponeurosis is composed are to a certain extent discernible, since the lines along which the fibres of the three muscles pass into the aponeurosis do not coincide, that of the external oblique extending from the outer border of the rectus muscle above obliquely downward and laterally to the anterior superior spine of the ilium, while those of the internal oblique and transversus follow essen-

tially the outer border of the rectus, except below, where they lie a little lateral to that muscle. More medially, however, the layers become intimately associated and can only be separated artificially.

At the outer border of the rectus muscle the aponeurosis divides into two layers (Fig. 529, A) which pass one in front and the other behind the rectus, thus forming a sheath for it (**vagina musculi recti**). The line of the division is indicated on the surface of the abdomen by a slight groove, and constitutes what is termed the *linea semilunaris*. When they reach the mesial border of the rectus the two layers unite and become continuous in the middle line with the aponeurosis of the opposite side to form a strong fibrous band which extends from the front of the xiphoid process of the sternum above to the symphysis pubis below, and is termed the *linea alba*. In its upper part this band is fairly broad, but below the umbilicus, which is situated in the band, it suddenly narrows to a thin line which becomes continuous below with the superior pubic ligament, behind the insertion of the recti, by a triangular expansion which occasionally contains muscle-fibres and is termed the **adminiculum lineae albae.**

Fig. 528.

Superficial dissection of abdomen, showing ventral aponeurosis.

The *posterior layer* of the aponeurosis, which forms the posterior wall of the sheath of the rectus, is fairly thick above, but a little below the level of the umbilicus it suddenly becomes very much thinner along an arched line, the concavity of which is downward, and may sometimes be represented by a distinct fold. This margin is termed the *line* or *fold of Douglas* (**linea semicircularis**) (Fig. 523).

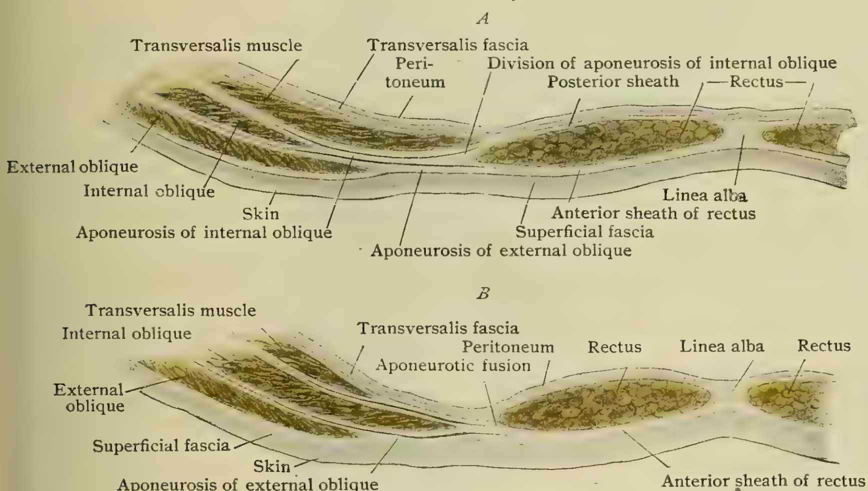
Various suggestions have been made in explanation of this sudden change in the thickness of the posterior layer of the sheath of the rectus. It has been supposed that it was connected with the passage of the inferior epigastric artery into the substance of the muscle (Henle), a somewhat inadequate cause even if the point of passage of the artery through the sheath corresponded with the semicircular line. The thinness of the portion of the sheath below the line has been explained on the ground that it represents the portion with which the urinary bladder was in contact in fœtal life (Gegenbaur), and also by the view that the strain exerted on this portion of the sheath is less than that placed upon the upper part, since the latter is acted on by fibres of the oblique and transverse muscles which have bony attachments drawn upward during inspiration, while the lower part is in relation to the less active fibres attached to the inguinal ligament (Solger).

Finally, it may be stated that the immediate cause for the sudden change in thickness has been assigned to the development of the processus vaginalis peritonæi, the pouch of peritoneum which in the embryo descends into the genital swelling and gives rise in the male to the tunica vaginalis testis. The formation of this peritoneal pouch is held to prevent the lower portions of the posterior layer of the abdominal aponeurosis which are derived from the aponeuroses of the internal oblique and transversalis from passing behind the rectus muscle, the posterior wall of its sheath being formed only by the fascia transversalis (Eisler).

In the lower part of the anterior abdominal wall the lowermost fibres of the abdominal aponeurosis—those extending between the anterior superior spine of the ilium and the pubic spine—form a strong ligamentous band, the **ligament of Poupart** (**ligamentum inguinale**) (Figs. 524, 530), the outer portion of which gives rise to some of the fibres of the internal oblique and transversalis muscles, while the fascia lata of the thigh is attached to it below. Near its medial end some of its fibres pass inward to be attached to the ilio-pectineal line of the pubis, forming a horizontal triangular sheet whose free concave lateral border forms the medial boundary of the *femoral ring* (**annulus femoralis**) through which the femoral hernias make their exit from the pelvis. This reflection (Fig. 531) is the **ligament of Gimbernat** (**ligamentum lacunare**). Furthermore, a sheet of fibres, variable in its development and termed the *triangular fascia* (**ligamentum inguinale reflexum**), or *ligament of Colles* (Fig. 1485), is reflected upward and medially from the inner portions of Poupart's and Gimbernat's ligaments in front of the lower medial portions of the aponeuroses of the internal oblique and transversalis muscles to the anterior layer of the sheath of the rectus.

The Inguinal Canal.—At an early stage in the development of the fœtus an outpouching of the lower part of the abdominal wall occurs on each side to form the genital swellings, which later become the scrotum in the male and the labia majora

FIG. 529.



Diagrams showing constitution of sheath of rectus muscle. *A*, in upper three-fourths; *B*, in lower fourth.

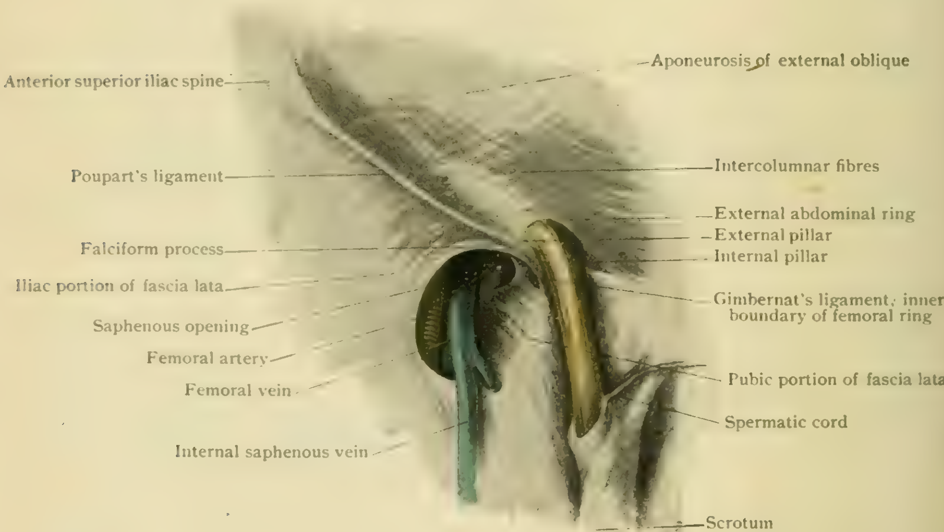
in the female. The points at which the outpouchings occur are those at which the lower ends of a ligament descending from the primitive kidneys (mesonephri) are attached to the abdominal wall, and these ligaments, consequently, are carried through the length of the outpouching beneath its peritoneal lining to attach to the walls of the scrotum or the labia. In the female the ligaments become in part the round ligaments of the uterus, but in the male the relations of the outpouchings become more complicated. Owing to the descent into them of the testes (page 2040), the ligaments are drawn completely into the pouch, forming the gubernacula of the testes, while the vasa deferentia and the vessels and nerves of the testes are also carried into the pouch, uniting to form the spermatic cord. There are, consequently, passing from the abdominal cavity into each pouch, in the female the round ligaments of the uterus and in the male the spermatic cord.

At first, and in the male for a considerable time after birth, the communication of the pouch with the abdominal cavity is widely open; but later, in the upper part of the pouch in the male and throughout its entire length in the female, the lumen becomes reduced, and finally is completely obliterated by the union of its walls to the spermatic cord or the round ligament, its lower portion persisting in the male as the space which exists between the visceral and parietal layers of the tunica vaginalis testis.

As a result of these processes the lower portion of the abdominal wall is traversed on either side by the spermatic cord or by the ligamentum teres of the uterus, and it is customary to regard the space occupied by the one or the other of these structures as a canal, which is termed the **inguinal canal.** It should be understood, however, that an actual space surrounding the cord or ligament does not exist, the walls of the canal being united to the structure contained within it. Nevertheless, the union is by no means a strong one, the region of the abdominal wall traversed by the ligamentum teres or especially by the spermatic cord being relatively weak and not infrequently the seat of an inguinal hernia.

The inguinal canal is somewhat over 3 cm. (1 1/2 in.) in length and is situated immediately above Poupart's ligament, which it crosses obliquely from above downward, medially, and forward. Its upper or inner end is about midway between the anterior superior spine of the ilium and the spine of the pubis, and lies about 12 mm. (1/2 in.) above the line of Poupart's ligament. It is marked by a more or less distinct depression on the posterior surface of the abdominal wall surrounding the spermatic cord or round ligament, termed the **internal abdominal ring** (**annulus inguinalis**

FIG. 530.

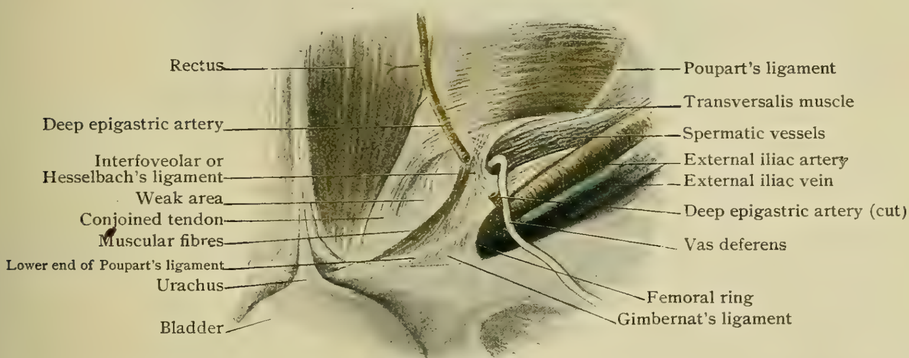


Dissection of right inguinal region, showing external abdominal ring and saphenous opening.

abdominis). The depression (Fig. 532) is due to the transversalis fascia being prolonged downward over the spermatic cord as a funnel-like sheath, the *infundibuliform fascia*. The lower or medial end of the canal corresponds to the **external abdominal ring** (**annulus inguinalis subcutaneus**) (Figs. 523, 530), and lies just lateral to and a little above the spine of the pubis and is surrounded by the lower medial portion of the aponeurosis of the external oblique. The fibres of the aponeurosis which bound this ring are somewhat thickened, forming what are termed the *pillars* (crura) of the ring, the uppermost of which, the *internal pillar* (**crus superior**), consists of fibres passing to the symphysis pubis; the lower one, the *external pillar* (**crus inferior**), is formed by the fibres passing to the pubic spine, and corresponds to the medial end of Poupart's ligament. Stretching across between the two crura are numerous obliquely arching *intercolumnar fibres* (**fibrae intercrurales**) which extend laterally almost as far out as the anterior superior spine of the ilium. From the margins of the external ring an attenuated prolongation of the aponeurosis of the external oblique is continued downward over the spermatic cord as a thin membrane known as the *intercolumnar* or *external spermatic fascia*.

Owing to the oblique direction of the canal, that portion of the aponeurosis of the external oblique which is strengthened by the intercolumnar fibres, together with a portion of the internal oblique, forms its anterior wall, while its posterior wall is formed by the aponeurosis of the transversalis, together with the more medial lower portion of that of the internal oblique, these two layers of fascia uniting in this region to form what is termed the *conjoined tendon*, which is attached below to the body and superior ramus of the pubis, and medially is especially thickened to form a band, the **falx inguinalis**, firmly attached along its medial border to the tendon of the rectus. More laterally, where it forms the medial boundary of the internal abdominal ring, it is also thickened (Fig. 531), forming the *ligament of Hesselbach* (**ligamentum interfoveolare**). Between these two thickenings the abdominal wall is weaker (Fig. 1493) and may give way to internal pressure, permitting a hernia, which comes to the surface at the external abdominal ring without having traversed the inguinal canal, and is therefore spoken of as a *direct* hernia, in contradistinction to the more usual *oblique* hernia which enters the canal at the internal abdominal ring.

FIG. 531.



Dissection of posterior surface of anterior abdominal wall, showing relations of conjoined tendon and its expansions to internal abdominal ring.

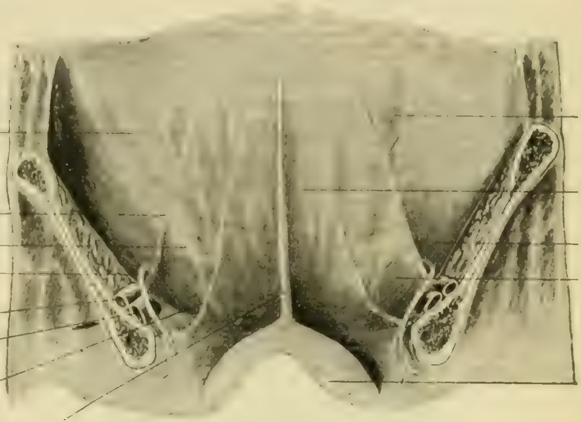
A small fasciculus of muscle-tissue is sometimes found close to the medial border of the internal abdominal ring. It is the *m. interfoveolaris* (Fig. 531), and arises from the superior ramus of the pubis, passing almost directly upward to spread out on the posterior surface of the transversalis. It is generally regarded as an aberrant portion of the transversalis muscle.

The Posterior Surface of the Anterior Abdominal Wall.—Throughout its entire extent, with the exception of a small area in the median line below, the posterior surface of the anterior abdominal wall is lined by peritoneum. In the exceptional area the peritoneum is kept from actual contact with the wall by a band of fibrous tissue, the *urachus*, which extends from the apex of the urinary bladder to the umbilicus and supports the peritoneum somewhat in the manner of a ridge-pole of a tent, so that between it and the abdominal wall there is an interval occupied only by loose areolar tissue and termed the *prevesical space of Retzius* (page 1906).

Laterally from the urachus a fibrous cord, the *lateral ligament of the umbilicus*, may be seen on each side, passing from the side of the bladder to the umbilicus and representing the obliterated hypogastric arteries of the fœtus ; while still more laterally there may be seen coming from the external iliac artery the inferior or deep epigastric artery, which, passing immediately to the inner side of the internal abdominal ring and posterior to the interfoveolar ligament (Fig. 532), extends upward and inward to penetrate the posterior layer of the sheath of the rectus a short distance below the level of the umbilicus. Both these structures produce a slight ridging or fold of the peritoneum, that formed by the obliterated hypogastric artery being termed the *plica umbilicalis lateralis*, while the other is the *plica epigastrica*. These two folds, together with the urachus, mark off the lower portion of the abdominal wall

into three areas or foveæ (Fig. 532). The median of these foveæ lies between the urachus and the lateral umbilical fold and forms the *supravesical fossa*, having for its floor the rectus muscle. Between the lateral umbilical and the epigastric folds is the *inner inguinal fossa*, having for its floor the conjoined tendon, and being therefore the region in which direct inguinal hernias arise; and lateral to the epi-

FIG. 532.



Posterior surface of anterior abdominal wall of formalin subject.

gastric fold is the *outer inguinal fossa*, in whose floor is found the internal abdominal ring, just to the outer side of the deep epigastric artery.

The triangular area bounded by Poupart's ligament below, the lateral edge of the rectus muscle medially, and the plica epigastrica laterally has been termed the *triangle of Hesselbach*. It is almost identical with the middle inguinal fossa, and defines a little more precisely the seat of the direct hernias.

(*c*) THE HYPOSKELETAL MUSCLES.

It seems probable that the psoas major and the psoas minor muscles are, in part at least, assignable to the group of abdominal hyposkeletal muscles. The close association of the psoas major with the iliacus and its attachment to the femur make it convenient, however, to defer their description until later (page 623).

PRACTICAL CONSIDERATIONS.

THE ABDOMEN.

The *abdominal cavity* is bounded above by the diaphragm; below by the floor of the pelvis; laterally by the diaphragm, the lower ribs, the abdominal muscles, and the lateral expansions of the ilia; posteriorly by the diaphragm, the tenth, eleventh, and twelfth ribs, the lumbar muscles and vertebræ, the posterior portions of the ilia, and the ischial, sacral, coccygeal, and pubic bones; and inferiorly by the levatores ani and coccygei muscles. It should be noted that the roof, the floor, and much of the remaining parietes of the abdomen are made up of muscular tissue which, by contraction or by relaxation or stretching, can alter the size of the cavity, affect the relations of the contained viscera, and vary the compression to which they are subject. The tonicity of the muscular walls brings about a normal intra-abdominal pressure which serves in health to retain in position and to give support to the viscera. This pressure is increased in inspiration and by straining, lifting, or coughing. It then, by increasing the outward pressure of the viscera upon the internal surface of the parietes, favors the production of hernia, the protrusion of the intestine

through a wound, the stretching of scars, and some forms of dystocia and of uterine displacement.

The *pelvic cavity*—"a recess leading downward and backward from the abdominal cavity proper" (Cunningham)—is divided from the latter by an imaginary plane extending from the promontory of the sacrum to the upper edge of the pubes. It will be considered separately.

The general shape of the abdominal cavity is described on page 1615 as are also the regions into which, for convenience, the abdomen proper may be divided by certain arbitrary lines (page 1615).

The structures and organs underlying the spaces thus marked out are approximately as follows:

RIGHT HYPOCHONDRIAC. Greater part of right lobe of liver, hepatic flexure of colon, and part of right kidney.	EPIGASTRIC. Greater part or whole of left lobe and part of right lobe of liver, with gall-bladder, part of stomach, including both orifices, first and major portion of the second parts of duodenum, duodeno-jejunal flexure, pancreas, upper or inner end of spleen, parts of kidneys, and suprarenal bodies.	LEFT HYPOCHONDRIAC. Part of stomach, portion of spleen, tail of pancreas, splenic flexure of colon, part of left kidney, and sometimes part of left lobe of liver.
RIGHT LUMBAR. Ascending colon, part of right kidney, and sometimes part of ileum.	UMBILICAL. Greater part of transverse colon, lower portion of second and much of third part of duodenum, some convolutions of jejunum and ileum, with portions of mesentery and greater omentum, part of right, often of left, and sometimes of both kidneys, and part of both ureters.	LEFT LUMBAR. Descending colon, part of jejunum, and sometimes part of left kidney.
RIGHT ILIAC. Cæcum with vermiform appendix and termination of ileum.	HYPOGASTRIC. Convolutions of ileum, bladder in children, and when distended in adults also, uterus when in the gravid state, and, behind, sigmoid flexure.	LEFT ILIAC. Sigmoid colon, convolutions of jejunum and ileum.

The contents of the various regions and the structures intersected by the different planes—if the arbitrary lines are continued into planes—vary considerably within normal limits and greatly in the presence of disease.

The *shape* and *size* of the abdomen are also extremely variable. In the normal adult male it is irregularly cylindrical, with a central bulging, an antero-posterior flattening, and a greater width near the pelvis than near the ribs. In the adult female the larger relative size of the lower abdomen is due to the greater development of the pelvis, and usually to flabbiness of abdominal muscles and accumulation of fat from want of exercise, and to compression of the upper segment by corsets; it is increased by the stretching of repeated pregnancies. In infancy and childhood the abdomen is prominent on account of the undeveloped condition of the pelvis, the pelvic viscera being then practically within the abdomen, and is broader above than below by reason of the relatively great bulk of the liver.

In obesity the weight of the intra-abdominal and subcutaneous fat carries the lower part of the abdominal wall downward by gravity, stretches it, and produces a *pendulous* abdomen. This condition is also favored by ascites, pregnancy, etc. In

emaciation the whole anterior abdominal wall becomes concave (*scaphoid*), especially the upper portion bounded by the ensiform cartilage and the subcostal angle,—the *scrobiculus cordis* (page 171),—which, with the patient supine, may appear to rest directly upon the vertebral column, with walls more nearly vertical than horizontal.

Congenital deformities of the abdominal wall usually consist in a failure of the ventral plates to unite in the middle line, producing various degrees of umbilical hernia (*q.v.*) or leaving the contents of the abdomen uncovered over a considerable area.

Contusions of the anterior abdominal wall, bounded laterally by the outer free border of the external oblique,—*i.e.*, by a line just external to a vertical line dropped from the lowest part of the ninth rib,—are of importance in relation to the effect upon the organs contained within the abdomen. As the skin over the abdomen and the abdominal muscles receive their nerve-supply from the lowest six intercostal nerves and the branches of the anterior division of the first lumbar, the contraction of the muscles upon the approach of danger, if not voluntary, may be reflexly hastened at the moment of external application of force, and a protecting elastic barrier may thus be interposed between the latter and the abdominal contents. The rigidity caused by the contact of a cold hand with the abdominal surface, preventing palpation of the viscera beneath, affords a familiar illustration of the close relation between skin and muscles. The relation of the nerve-supply of the muscles and that of the underlying viscera explains the rigidity of the belly so usually seen in injury or disease of abdominal organs (page 1683). Finally the relation of the cutaneous and muscular branches of the intercostal nerves is well shown by the sudden inspiratory effort caused by a dash of cold water on the lower thoracic or abdominal region, six of these nerves supplying the intercostal muscles as well as the antero-lateral surface of the chest and belly.

The injurious effect of contusions is diminished by the presence of a thick layer of subcutaneous fat or by the interposition of a fleshy omentum. If the abdominal muscles are relaxed, serious injury to the viscera may be done without obvious damage to the parietes. Absence of ecchymosis or other visible sign of injury should therefore not lead to an absolutely favorable prognosis until after the lapse of sufficient time to permit of the development of visceral symptoms.

Wounds.—The thinness and loose attachment of the *skin* of the abdomen favor the occurrence of cellulitis as a result of infection from superficial wounds. The *superficial layer of the superficial fascia* contains the greater part of the subcutaneous fat and covers the superficial blood-vessels. The thickness of the abdominal wall depends chiefly upon the thickness of this fatty layer, which may be of several inches. An abdominal wound may therefore be of considerable depth and yet be attended by little or no bleeding and be practically "superficial." The *deeper layer of the superficial fascia* (page 515) is firmer, is elastic, and in its lower part is the vestige of the "tunica abdominalis," well developed in the horse and some other quadrupeds for reinforcement of the abdominal muscles, on which the weight of the viscera comes more directly than in man. It is attached in the middle line to the deeper structures and to the iliac crest, and below Poupart's ligament blends with the fascia lata of the thigh. It is not attached over the space between the pubic spine and symphysis, but, being carried downward over the spermatic cord, becomes continuous with the dartos layer of the scrotum and with the fascia of Colles. Cellulitis superficial to this layer may therefore spread in all directions, but beneath it is likely to be at least temporarily arrested at the lines of attachment indicated. General emphysema, effusions of blood, and collections of pus have for a time similar limitations. They are apt to be guided by this fascia into the space between the spine and the symphysis and to descend into the scrotum and towards the perineum, where the lateral attachments of Colles's fascia to the margins of the pubic arch and posteriorly to the base of the triangular ligament prevent their spreading in those directions. More usually the extravasation—blood, pus, or urine—gains this subfascial space below, as from rupture of the urethra anterior (inferior) to the triangular ligament (page 1932), and ascends to the abdomen by the same route, being prevented from crossing the mid-line or descending to the thighs by the attachments of the deep layer of the superficial fascia that have been described.

Wounds involving the *muscular layers* of the abdominal wall may gape widely, but the differing directions of the fibres of the external oblique, internal oblique, and transversalis tend to limit this just as they lessen the after-risk of ventral hernia and favor certain physiological acts, as the emptying of the bladder, the bowels, or the uterus. This difference of direction is taken advantage of in gaining access to the abdominal cavity in some operations (page 535).

Infection in the lateral *intermuscular spaces* usually spreads rapidly on account of the abundance of loose cellular tissue. The cellulitis or resulting abscess (or collection of blood or air) will be limited by the semilunar line in front, by the costo-chondral arch above, by Poupart's ligament and the crest of the ilium below, and by the edge of the erector spinæ behind; in other words, by the attachments of the muscles between which they spread (Treves).

Beneath the abdominal wall, practically making a portion of it, lies a layer of loose connective tissue—the *subperitoneal* or *subserous areolar tissue*—which connects the peritoneum with the parietes. "Extraperitoneal connective tissue" has been suggested (Eccles) as a better name for it. Infection of this tissue, whether from without, as in the case of wounds, or by extension from some of the viscera lying wholly or partly behind the peritoneum, as in perirenal abscess or certain forms of appendiceal abscess, is likely to spread widely. Abscesses, especially if chronic, often gravitate into the iliac fossa and are arrested at Poupart's ligament by the junction of the transversalis and iliac fasciæ, constituting a form of *iliac abscess*. If they are incised here, it will usually be necessary to go through only the abdominal muscles and aponeuroses, including the transversalis fascia, as the looseness and abundance of the subserous tissue will have permitted the abscess to dissect off and push upward the peritoneum. If the patient is supine, pus in the iliac fossæ—*i.e.*, in the shallow lower zone of the abdomen—may gravitate into the deep lateral recesses of the middle zone (page 1615), and it often takes this direction in cases in which the source of infection is an appendix situated behind the cæcum. It should be noted that a true iliac abscess is beneath the iliac fascia, and is therefore more apt to be guided by that fascia to the lowest point of the ilio-psoas space and to pass with the ilio-psoas muscle into the thigh, pointing at the outer side of the femoral vessels.

The laxity of the subserous tissue favors certain retroperitoneal operations—*e.g.*, uretero-lithotomy—by permitting the stripping forward of the peritoneum itself. The relatively great resistant power of the side of the peritoneum in contact with this tissue is subsequently described (page 1754). The fat contained in this layer—greatest in the lumbar region (*perinephric fat*) and in front of the bladder in the space of Retzius (the triangular interval defined by the symphysis pubis, the bladder, and the peritoneum), and abundant in the inguinal and iliac regions—may serve as a guide in approaching the peritoneum by incision, or may mislead if mistaken for the omental fat. The latter error has resulted, as, for example, in operation for ovarian cyst, in regarding the peritoneum as the cyst-wall, and in detaching it from the parietes over a wide area. This fat occasionally works its way through intervals between the fibres of the overlying fascia or muscles, especially along the linea alba, and constitutes the *subserous lipomata*, which, if large enough, are sometimes thought to be irreducible ventral herniæ. The laxity of the subserous areolar layer between the bladder and the posterior surface of the symphysis pubis permits the peritoneum to be carried up on the summit of a distended bladder as it rises into the abdomen and thus facilitates extraperitoneal access to the anterior vesical wall (page 1912). Its looseness over the iliacus muscle is a factor in the formation of the sac of inguinal hernia (page 1767). Wounds of the abdominal wall dividing this subserous layer, but leaving the peritoneum untouched, should practically be classified among *non-penetrating* wounds, although in a sense the abdominal cavity has been opened. The symptoms and dangers of infection will be as above enumerated. Wounds involving the peritoneum are called *penetrating* wounds, the dangers of which have been considered in the section on the peritoneum.

In the closing of abdominal wounds the irregularities that may result from the differing directions of the muscular fibres involved—causing greater retraction at one

point than at another—should be remembered. This may make accurate suturing in layers difficult, but such suturing, together with careful approximation of the edges of the peritoneal layer, is necessary to lessen the risk of ventral hernia.

The respiratory movements prevent the attainment of absolute rest during the healing of abdominal wounds, as they do after fractures of ribs; but in both cases approximate rest, as secured by strapping with adhesive plaster or by abdominal binders, gives excellent average results.

THE LOIN.

The *posterior abdominal wall* is in far less intimate association with the peritoneum or the small intestine, and is, in its relation to injury or disease, of less importance than the antero-lateral walls, but it will be convenient to consider it and the loin here. *Contusions*, if over the ilio-costal space,—the posterior segment of that portion of the abdominal wall which has no bony protection,—are apt, if severe enough, to result in injury to the friable kidneys (page 1891) rather than to the relatively strong and elastic ascending or descending colon. *Wounds*, if they pass through the entire thickness of the wall, may involve either of these structures. When they become infected, the resulting *cellulitis* or *abscess* will be influenced as to the direction it takes and in its limitations by the various fasciæ and muscular sheaths. The *subcutaneous connective tissue* is loose and abundant, and is frequently the seat of suppuration or of extensive collections of blood which gravitate towards the iliac crest or pass below it. The boundaries of effusion into the *intermuscular spaces* external to the edge of the erector spinæ have already been described (*vide supra*). Within the musculo-aponeurotic compartments made by the splitting of the strong lumbar fascia into three layers (page 508) and enclosing the erector spinæ and quadratus lumborum muscles the products of suppuration may for a time be confined. The middle and posterior layers are, moreover, very dense and resistant, and therefore, as they form the sheath of the erector spinæ, that muscle is rarely the seat of abscess of other than vertebral origin; beginning in caries of the neural arches, however, an abscess may directly penetrate the muscle between its fibres of origin or insertion. The anterior layer, separating the quadratus lumborum from the subserous areolar tissue, is very thin and is continuous with the transversalis fascia. For this reason, abscesses originating about the kidney or around the cæcum or sigmoid not infrequently perforate this layer and pass either directly through the outer third of the thin quadratus lumborum external to the erector spinæ (which buttresses its inner two-thirds) or through the transversalis fascia external to the quadratus. If they are high (perirenal), they may follow the last dorsal nerve, which pierces this fascia and the transversalis muscle just below the last rib, and may then make their way through the internal oblique and appear at the outer border of the erector spinæ; or they may gravitate to the triangle of Petit,—the interval between the crest of the ilium (its base) and the converging edges of the external oblique and latissimus dorsi,—where, as the floor of the triangle is formed by the internal oblique, they will be subcutaneous as soon as they have perforated the latter muscle. An abscess of lower origin (pericæcal, pericolic) may reach the same space by following the ilio-hypogastric branch of the first lumbar nerve.

Abscesses in the *lumbar subserous areolar tissue* are more frequent on the right side, on account of the presence of the appendix. Like abscesses of perinephric origin occupying the same situations, they may open into the colon or sigmoid. As this tissue is continuous below with the corresponding layer in the pelvis, abscesses originating there may ascend and appear at one or other of the various points described. True iliac abscesses (*vide supra*) are beneath the iliac fascia, which is continuous with the transversalis fascia at Poupart's ligament, but encloses the ilio-psoas muscle in a definite compartment, weak below, where the fascia accompanies the muscle beneath Poupart's ligament to become the pectineal fascia. The upper part of this fascia, covering the psoas muscle, is thinner and less resistant than the lower. Abscesses beginning in disease of the lumbar spine may penetrate directly into the muscular substance. Those beginning in the thoracic spine are often so limited anteriorly by the internal arcuate ligament and posteriorly by the spine and last rib

that they are diverted into the psoas sheath between those slips of origin of the muscle which come from the bodies of the vertebræ and those which come from the transverse processes. Often the pus descends, as in iliac abscess, to point on the thigh external to the femoral vessels, but not infrequently it passes under the external arcuate ligament or penetrates the psoas sheath at its outer edge and the anterior layer of the lumbar aponeurosis (to which it is there attached) and points in the loin, in which case it may be mistaken for one of the abscesses originating in or spreading through the subserous areolar tissue.

In the typical psoas abscess the thigh is flexed to relax the muscle and its sheath and to lessen the compression of the lumbar nerves which are contained within it. It will be observed that a psoas or a true iliac abscess is in close relation to these nerves, but is separated from the iliac vessels and, except at the upper portion, from the genito-crural nerve by the thick iliac fascia. Iliac aneurism may, however, by pressure cause flexion of the thigh and pain in the course of the same nerves.

LANDMARKS AND TOPOGRAPHY OF THE ABDOMEN.

1. The *bony and cartilaginous structures* that constitute the apparent limits of the abdomen, and that are either visible or palpable, are as follows:

(*a*) The *tip of the ensiform cartilage*, on a level with the lower part of the body of the tenth dorsal vertebra. (*b*) The *seventh*, *eighth*, *ninth*, and *tenth costal cartilages*, forming the lateral boundaries of the infrasternal fossa (Fig. 173, page 171). A notch that may be felt on the costal border indicates the point of union of the tip of the tenth to the edge of the ninth cartilage (Woolsey). (*c*) The *tips of the eleventh and twelfth costal cartilages* are free, except as they are connected with each other by the intercostal and abdominal muscles. Sometimes the twelfth rib is rudimentary and does not project beyond the external edge of the erector spinæ muscle. Hence in planning operations that open the abdominal cavity just below that rib—as in nephrotomy—it is well to count the ribs from above; otherwise the pleura might be opened by mistake (Fig. 1581). (*d*) The *spines of the lumbar vertebræ*, corresponding to their bodies and representing the posterior bony wall of the abdomen, are useful landmarks. Their relation to the abdominal contents as to level has been described (page 148). (*e*) The *crest of the ilium*, the *anterior and posterior iliac spines*, and the *pubic spine and symphysis* have been described (page 349).

2. The *skin* is usually creased or furrowed in proportion to the amount of subcutaneous fat or—in thin persons—to the muscular development. In fat persons two deep *transverse furrows* form across the abdomen. In the upper one, which intersects the umbilicus, the latter may be completely concealed. The lower one runs just above the crest of the pubes. Its point of intersection with the linea alba is a convenient landmark for the introduction of the trocar in suprapubic tapping of a distended bladder. It is of use in the diagnosis of femoral hernia (page 1774).

In cases of ankylosis of the hip-joint transverse creases may be seen running across the belly between the umbilicus and the pubes. They are produced by the freer bending of the spine that is apt to occur in such cases, the absence of some of the simpler movements of the hip-joint in flexion and extension being compensated for by increased motion of the vertebral column (Treves).

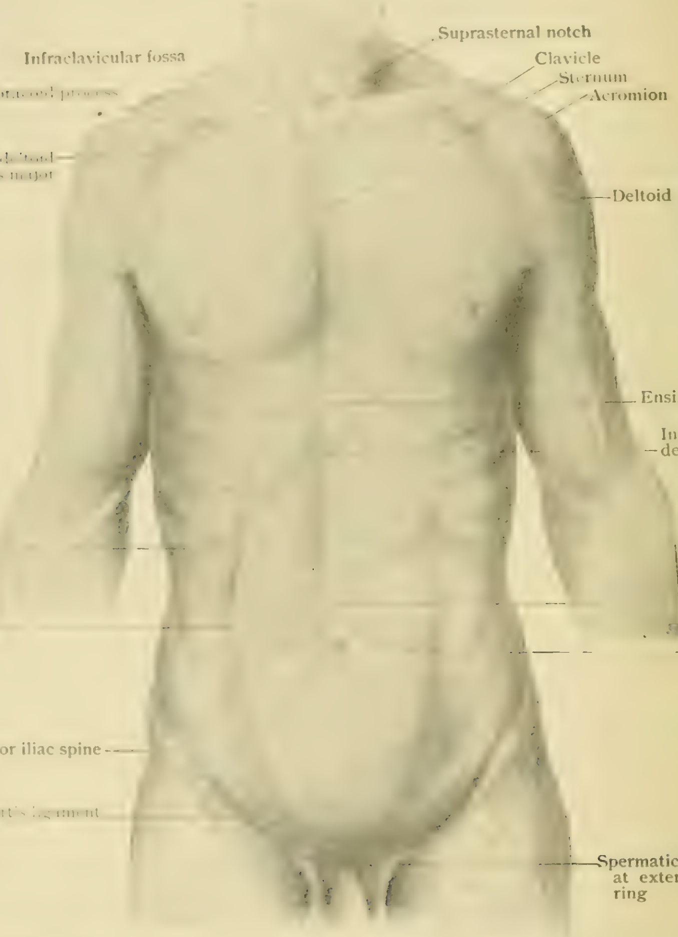
The *striæ gravidarum* are sinuous, silvery streaks, resembling scars, that follow atrophy of the connective-tissue layers of the skin from stretching due to abdominal distention, as in pregnancy, ovarian cysts, or ascites.

3. *Intermuscular or Interfascial Markings.*—The *linea alba*—the fibrous raphe formed by the union of the sheaths of the recti at their inner borders—may be seen as a very shallow groove extending from the ensiform cartilage to the umbilicus. Below the tip of the xiphoid this may be a quarter of an inch in breadth, and it is apt to be slightly wider just above the umbilicus. From a little below that level—one to two inches—it cannot be seen, as until it nears the symphysis it is merely a line of fibrous tissue resulting from the coalescence of the sheaths. A little

above the symphysis it widens into a narrow triangle (adminiculum), but is still not visible on account of the suprapubic fat. It may be congenitally much wider than normal, or may be stretched by abdominal swellings, and in either case may be the seat of ventral hernia. The absence of blood-vessels in and over the linea alba and its thinness lead to its selection as the site of the incision in many abdominal operations.

The *linea semilunaris*, corresponding to the other border of the sheath of the rectus muscle, may be seen when the rectus contracts as a curved line from 6.5 to 7.5 cm. ($2\frac{1}{2}$–3 in.) external to the linea alba, at the level of the umbilicus, with its

FIG. 533.



Anterior surface of trunk, from photograph of living model; bony landmarks have been somewhat exaggerated.

concavity inward, extending from the tip of the ninth costal cartilage to the spine of the pubes. As it marks the point of division of the abdominal aponeuroses (Fig. 529) to form the sheath of the rectus, it also marks a frequent line of limitation of emphysematous, hemorrhagic, or purulent extravasations in the lateral intermuscular spaces (*vide supra*).

The *lineæ transversæ*, which may also be seen as shallow grooves when the rectus is in action, and are most marked in muscular persons, correspond to the tendinous intersections that interrupt the longitudinal fibres of the rectus. They are the representatives of the intersegmental septa which separate the original

myotomes giving rise to the muscles of the abdomen; in some of the lower vertebrates (reptiles) these intersections are replaced by bony bars, as seen in the abdominal ribs of crocodiles and some lizards (*Hatteria*). The highest is about the level of the tip of the ensiform cartilage, the next at that of the tenth rib, the third at the umbilicus. Very rarely a fourth line is seen below this level. The second and third are the most constant, and divide the upper part of each rectus into two nearly quadrilateral portions, easily seen in athletic subjects. These bands tend to prevent overstretching or rupture of the rectus in cases of great abdominal swelling or of violent contraction. The anterior sheath of the rectus is adherent to these fibrous bands. Hence an abscess or a collection of blood on that aspect of the muscle may be confined to the space between any two of them. Posteriorly this is not the case. Spasmodic contraction of the rectus fibres in one of these divisions of the rectus is the cause of one variety of "phantom tumor," the swelling appearing and vanishing with contraction and relaxation of the fibres,—a phenomenon most frequently seen in neurasthenics, but which in this instance may occasionally indicate a reflex disturbance based on some deep-seated source of irritation. Treves has seen, for example, this condition associated with cancer of the stomach, duodenal ulcer, and malignant disease of the peritoneum.

The *inguinal groove* runs with a slight downward curve from the anterior superior iliac spine to the pubic spine and corresponds to Poupart's ligament. As this latter structure results from a thickening of the lowest fibres of the aponeurosis of the external oblique, and as the internal oblique and transversalis muscles arise from its outer half, it follows that, by reason of its direct continuity with the fascia lata, extension of the thigh on the trunk increases the tension of the anterior abdominal wall. Hence in abdominal examinations the thighs are flexed on the abdomen to lessen this tension. At the same time the shoulders and trunk should be slightly elevated to relax the recti.

Posteriorly the *spinal* furrow marks the interval between the erector spinæ muscles and the line of attachment of the skin to the tips of the lumbar spines. Farther out the outer edge of the erector spinæ is palpable and often visible, except in very fat persons. Occasionally the posterior free edge of the external oblique may be seen when it is not overlapped by the latissimus dorsi.

4. The *umbilicus*, except as a landmark, is of chief interest in relation to hernia, in connection with which it will be described. The creases around and between the folds of skin forming the umbilical papilla are difficult to sterilize, and should receive especial attention before operation.

Fistulæ at the umbilicus may be *urinary* and due to a patent urachus (page 1911), or *fecal*, resulting from a persistent vitello-intestinal duct,—Meckel's diverticulum (page 1652).

5. *The Vessels.*—The most important *artery* is the deep epigastric (*q.v.*), but branches of the deep circumflex iliac, the last two intercostals, and the abdominal branches of the lumbars may require ligation during various abdominal operations. The course of the deep epigastric artery, which is sometimes the source of troublesome hemorrhage, should be remembered in studying the anterior wall of the abdomen. A line drawn with a slight inward curve from the junction of the inner and middle thirds of Poupart's ligament towards the umbilicus, crossing the outer edge of the rectus muscle about one-third the distance between the level of the symphysis pubis and that of the navel, will indicate the course of the lower part of this vessel. At the internal abdominal and the femoral rings it has important relations to hernial sacs (page 1493); it lies at first at the side of the rectus in the subserous areolar tissue, then in the transversalis fascia, then within the sheath of the rectus (above the fold of Douglas) behind the middle of the muscle, and finally in the muscle itself. It therefore runs from without inward and becomes more superficial as it ascends.

With the exception of the superior epigastric and ascending lumbar, all the abdominal and pelvic *veins* empty directly or indirectly into the inferior vena cava and are therefore affected by the conditions that obstruct that vessel; hence the superficial veins are often varicose. Although their varicosity is usually a result of obstruction in the portal vein or inferior vena cava, it may occur independently of

obstructive cause, as do many cases of varicose veins of the lower extremity, and may be very large and extremely tortuous (*caput medusæ*).

The mechanism of the production of this form of varicosity by portal obstruction will be more readily understood by reference to Fig. 534, which also explains other phenomena associated with that condition.

The superficial epigastric vein is often visible. Through its anastomosis with the deep and superior epigastric veins it is connected with the portal and parumbilical veins and may be enlarged as a symptom of hepatic disease (page 1727).

The area of redness about the umbilicus seen in some forms of peritonitis is probably due to inflammation extending along the obliterated umbilical vein (page 1757).

The surface veins above the umbilicus empty into the axilla and those below that level into the groin, but the venous currents may be reversed by disease. For example, the superficial epigastric and superficial circumflex iliac normally empty into the internal saphenous vein a little below Poupart's ligament. In cases of obstruction of the inferior vena cava the blood-current is reversed (as it is in the corresponding deep veins), they enlarge, and, by anastomosing with the superior epigastric, internal mammary, and thoraco-epigastric veins, carry blood from the lower limbs into the axillary or innominate, and so into the superior vena cava.

In hepatic obstruction, although the superficial epigastric may become varicose (through its connection with the parumbilical and portal veins), this reversal of the blood-current does not occur in it, as may be shown by emptying the vein by pressure and observing the direction of the current as it refills.

FIG. 534.

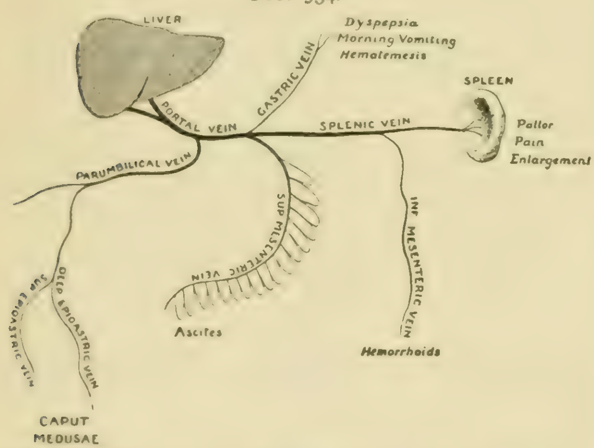


Diagram showing anatomical relations of certain clinical phenomena in cirrhosis of liver. (*After Hare and Taylor*.)

The superficial *lymphatics* of the abdominal wall below the umbilical level empty into the nodes at the groin, those above that level into the nodes in the axilla.

6. The *nerves* of the abdominal wall (page 535) have already been described in their relation to various clinical phenomena (pages 1683, 1755). In addition, it should be said here that the definiteness of the relation in nerve-supply between cutaneous areas and abdominal organs is often of great value in diagnosis. As the sixth to the twelfth thoracic and the first lumbar spinal segments aid in the nerve-supply to the abdominal viscera, and as the corresponding spinal nerves supply the skin of the abdomen, pain due to visceral disease is often referred (through the communicating branches with the splanchnic and the sympathetic visceral nerves) to the peripheral terminations on the skin of the abdomen, which may even be sensitive to the touch.

It is possible to map out approximately on the surface the area of distribution of the cutaneous branches from each of these segments (Fig. 535).

Head has associated as follows these areas (which are almost identical with the areas of distribution of the corresponding spinal nerves) and the viscera in closest connection with them :

The sixth, seventh, eighth, and ninth thoracic segments with the stomach ; the ninth, tenth, eleventh, and twelfth thoracic segments with the intestinal tract ; the seventh, eighth, ninth, and tenth thoracic segments with the liver and gall-bladder ; the tenth, eleventh, and twelfth thoracic and the first lumbar segment with the kidney and ureter ; the second, third, and fourth sacral with the rectum.

The distribution to the pelvic organs will be considered later, but it may be said here that the pelvic viscera are supplied from the fifth lumbar to the fourth sacral segment and that no visceral branches emerge from the second, third, or fourth lumbar segments.

Division of any of the motor nerves interferes with the function and ultimately with the nutrition of that portion of the musculature of the abdominal wall that is supplied by them, giving rise to weakness over that area, favoring the development of ventral hernia, and, if extensive, interfering with the physiological action of those muscles in defecation, urination, or parturition.

For clinical purposes these nerves may be divided into three groups (Eads): (*a*) the seventh and eighth intercostals ascend obliquely and supply the upper third of the abdominal wall; (*b*) the ninth and tenth intercostals run horizontally inward and supply the middle third; (*c*) the eleventh intercostal, the last thoracic, and the ilio-hypogastric and ilio-inguinal nerves run obliquely downward and inward and supply the lower third.

It is obvious that vertical incisions elsewhere than in the linea alba (the nerves do not cross the mid-line) will divide a larger number of these nerves and result in more extensive atrophy of abdominal wall than will incisions more nearly parallel with the nerves and, when possible, with the chief muscular fibres of the region involved.

FIG. 535.

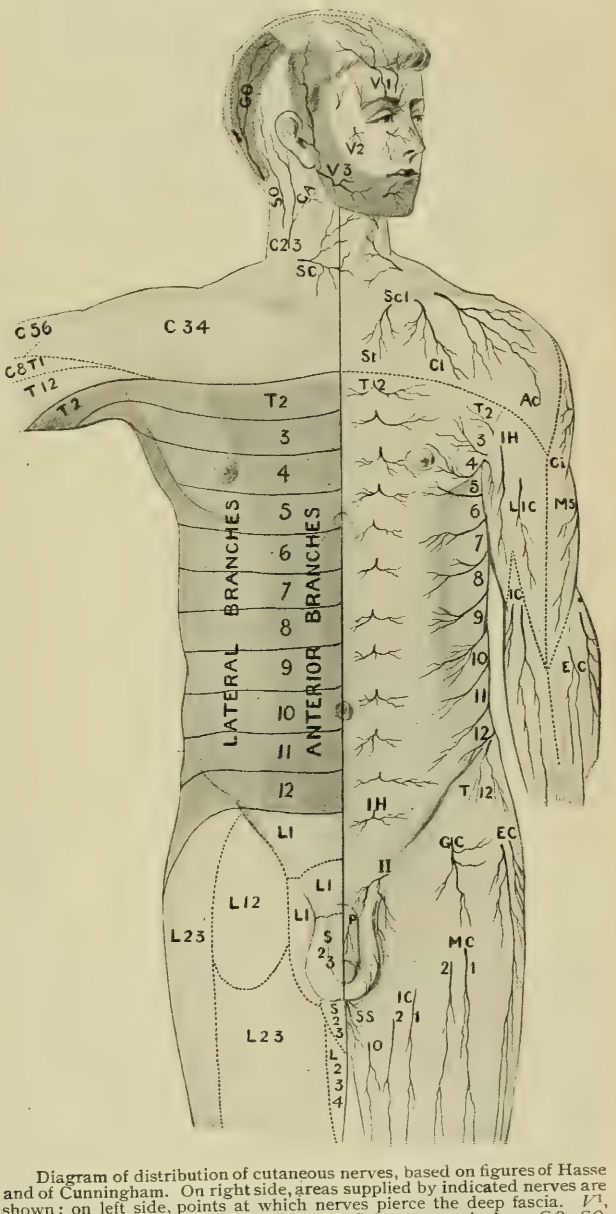


Diagram of distribution of cutaneous nerves, based on figures of Hasse and of Cunningham. On right side, areas supplied by indicated nerves are shown; on left side, points at which nerves pierce the deep fascia. V^1, V^2, V^3, divisions of fifth cranial nerve; *GA*, great auricular; *GO*, *SO*, greater and smaller occipital; *SC*, superficial cervical; *St*, *Cl*, *Ac*, sternal, clavicular, and acromial branches of supraclavicular (*Scl*); *Ci*, circumflex; *MS*, musculo-spiral; *IH*, intercosto-humeral; *LIC*, *IC*, lesser internal and internal cutaneous; *EC*, external cutaneous; *IH*, ilio-hypogastric; *II*, ilio-inguinal; T^{12}, last thoracic; *GC*, genito-crural; *EC*, external cutaneous; *MC*, middle cutaneous; *IC*, internal cutaneous; *P*, pudic; *SS*, small sciatic; *O*, obturator; *C*, *T*, *L*, and *S*, cervical, thoracic, lumbar, and spinal nerves.

The Anatomy of Abdominal Incisions.—A diagrammatic representation of the structures of the abdominal wall in their relation to the most important incisions may help to elucidate the practical application of some of the above-mentioned facts. It should be noted that in many of these incisions the approximately parallel fibres of the internal oblique and transversalis (where they are both muscular) may be regarded as one layer and

separated on the same line. No effort has been made, therefore, to show the latter muscle in the diagram.

Incisions Nos. 1, 2 and 3 are through the linea alba, No. 2 being carried around the umbilicus to the left to avoid the parumbilical vein and the round ligament of the liver. The chief advantage is the accessibility to the whole cavity afforded by prolonging the incision. The slight vascularity of the median raphe and the thinness of the abdominal wall, while operative advantages, tend to favor the later production of hernia.

Incision No. 4 combines the disadvantages of the incisions through the linea alba with the added interference with the nerve-supply to the rectus.

Incision No. 5 (McBurney) is described later (page 1685). It represents merely the separation of the aponeurotic fibres of the external oblique; the deeper wound separates the internal oblique and transversalis fibres transversely. It may be noted that its inward extension (Weir), even if it involves division instead of retraction of the rectus (page 1685), would equally avoid nerve-trunks, but might involve ligation of the deep epigastric. The resulting scar in the rectus would, however, merely add in effect another *linea transversa* and would not impair the efficiency of that muscle.

FIG. 536.

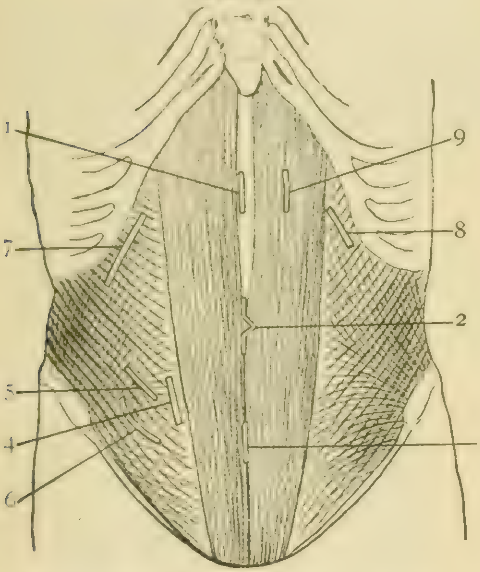


Diagram illustrating relations of various incisions to structures of abdominal walls.

Incision No. 6 (Eads) separates the same structures, but affords a better opportunity for approach to many appendicular abscesses without going through the peritoneal cavity (page 1685).

The incision for inguinal colostomy (page 1688) may be made on the same lines as those just described.

Incision No. 7, after division of the external oblique, permits the separation of the fibres of the internal oblique and of the upper abdominal intercostal nerves, which, like the others, run beneath that muscle, and is used to gain access to the gall-bladder region.

Incision No. 8 also respects the internal oblique fibres and the seventh and eighth intercostal nerves and, when used for gastrostomy, permits the development of a valvular or sphincteric action about the orifice (page 1633).

Incision No. 9—the vertical incision through the rectus recommended for gastrostomy (Howse)—must divide the terminal branches of the intercostal nerves, and consequently that portion of the muscle distal to the line of division will be weakened or paralyzed and unable to contribute to the formation of a sphincter (Eads).

The incision for lumbar colostomy is described later (page 1688). The remaining incisions through the loin may be more appropriately considered in relation to the approach to the kidneys or ureters (page 1894).

Anatomical Relations bearing on the Examination of the Abdomen.—Harris has suggested utilizing the fixed and circuitous route of the colon (Fig. 1383) to subdivide the abdominal cavity by taking the inner or mesial layers of the longitudinal mesocolons and the inferior layer of the transverse mesocolon as the dividing lines. We would thus obtain four regions,—namely, (1) the central region surrounded by mesocolon, (2) the superior region lying above the transverse mesocolon, (3) the right postero-lateral and (4) the left postero-lateral regions lying external to and behind the longitudinal mesocolons.

Tumors of special viscera begin, as a rule, in the region normally occupied by

those organs, and often, when they overlap its boundaries, displace the colon in definite directions.

The course of the colon being made apparent by inflating it with air, it may therefore be said that:

1. Growth in the *central* region would include tumors of the omentum, mesentery, small intestine, and peritoneum, many retroperitoneal tumors, and such growths affecting the female generative apparatus as rise from the pelvis into the abdomen. In the latter case the cæcum and sigmoid would be displaced upward and outward.

2. Tumors beginning in the *superior* region would include those of the liver, gall-bladder, stomach, lesser omentum, spleen, and pancreas. Harris calls attention to the fact that pancreatic cysts have usually been mistaken for ovarian cysts, although the former almost always displace the transverse colon downward. They also, being retroperitoneal, carry it forward, while tumors of the spleen, although they cause downward displacement of the colon, especially of the splenic flexure, override it and hug the anterior abdominal wall. Enlargement of the gall-bladder similarly tends to depress and to overlap the right half of the transverse colon.

3 and 4. In the *postero-lateral* or *external* regions the most common tumors are those of the kidneys; but as they are all retroperitoneal, they tend to carry the ascending or descending colon forward as well as inward. There are, of course, exceptions to these relations,—as, for example, in the case of a movable kidney, which may be displaced so as to carry the inner layer of the mesocolon forward and inward and so have the colon lying to the outer side,—but they are rare, and the anatomical relations described are of distinct diagnostic value.

Bowlby has formulated the anatomical reasons for first exploring the right lower half of the abdomen in cases of intestinal obstruction of doubtful origin. He says that here are to be found: (*a*) the appendix; (*b*) intestinal diverticula perhaps attached to the umbilicus or to the neighboring mesentery; (*c*) a common site for volvulus,—that is, the cæcum; (*d*) a usual site for the lodgment of an impacted gall-stone,—that is, the lower part of the ileum; (*e*) a common place for adhesions due to caseous mesenteric glands; (*f*) the sites of right-sided inguinal, femoral, and obturator herniæ. Further, if the obstruction is in the small intestine, it is in the right iliac fossa that undistended intestine will be found, and if this can be secured and traced upward, it is the surest guide to the seat of obstruction.

A brief *résumé* of some of those symptoms of abdominal disease having a definite anatomical basis will serve to complete the consideration of this important region. The patient being supine with the thighs flexed:

1. *Inspection* may show: (*a*) an asymmetrical swelling referable to a particular organ or region (*vide supra*); (*b*) general distention, which, if due to ascites, will cause bulging of the flanks, the fluid settling in the deep lateral recesses of the middle zone; if to flatulence or intestinal paresis, a more symmetrical enlargement, usually somewhat emphasized in the central region on account of the presence there of the coils of thin and easily dilatable small intestine; if to pregnancy, a rounded central prominence in the lower abdomen; (*c*) retraction, which if extreme (scaphoid), might be due to tuberculous meningitis, to lead poisoning, or to other cause of great emaciation; (*d*) œdema of the skin, indicating, if local, an abscess underlying and close to or in the abdominal wall; (*e*) enlarged veins (*vide supra*); (*f*) a flattened umbilicus in ovarian or uterine growth, or a pouting umbilicus in ascites or tuberculous peritonitis.

2. *Palpation* may disclose: (*a*) rigidity of the abdominal wall, which, if in the right hypochondriac region, would suggest gall-bladder disease; if in the epigastric region, stomach ulcer or pancreatitis; if in the right iliac fossa, disease of the appendix or cæcum. The entire absence of rigidity in a case of acute abdominal pain, especially if the latter is relieved by pressure, indicates an absence of inflammation and suggests irregular or spasmodic peristalsis (colic) as the cause; (*b*) pulsation due to the upheaval of a growth by vessels beneath it, to an aneurismal swelling, or, in the line of the vessel and in thin persons, to the pulse in a normal aorta; (*c*) tenderness, which is sometimes misleading on account of the association of visceral disease and reflected surface pain (*vide supra*). For example, the characteristic tenderness of appendicitis is over McBurney's point, but there may be not only pain but also

tenderness in the umbilical region. The reflected pain of ovaritis may be beneath the costal margin or along the crural branch of the genito-crural nerve, where superficial tenderness may be elicited, whereas the deep pain is in the ovary itself (Mayo Robson).

3. *Pain* due to abdominal disease has been described in connection with the various viscera (page 1756).

4. Much information may be elicited by *percussion*, as the dulness in the flanks (movable on change of position) due to ascites, or the localized tympany due to volvulus or to the escape of gas from a ruptured appendix into a surrounding abscess; or by *auscultation*, as the absence of the usual intestinal sounds when a general peritonitis has arrested peristalsis; or by *inflation* of the stomach, as on distinguishing between a growth of that viscus and a retroperitoneal tumor, or of the colon (*vide supra*), which will then lie below and perhaps behind an enlarged gall-bladder and in front and probably to the inner side of an enlarged kidney.

These and other procedures are too technical to be described here in detail, but are mentioned that they may be associated with the anatomical relations on which they depend.

It should be noted that Treves and Keith state that the ileo-cæcal valve corresponds to the spino-umbilical line, that the region of the valve in a normal person is usually tender to pressure, and that the root of the appendix is placed more than one inch lower and perhaps more internally. This statement if confirmed will have a most important bearing on the value of certain symptoms thought to indicate the existence of appendicitis (page 1683).

THE THORACIC MUSCLES.

(*a*) THE RECTUS MUSCLES.

The rectus abdominis, being supplied by the lower intercostal nerves, is evidently a derivative of the thoracic myotomes. That portion of the rectus group of muscles which should be derived from the upper thoracic myotomes is normally unrepresented, although the occasional extension of the rectus abdominis to the upper costal cartilages or even to the clavicle is probably an indication of it.

(*b*) THE OBLIQUUS MUSCLES.

1. Intercostales externi.
2. Intercostales interni.
3. Triangularis sterni.
4. Levatores costarum.
5. Serratus posticus superior.
6. Serratus posticus inferior.

Here, again, a considerable portion of the obliqui and transversalis abdominis is derived from thoracic myotomes. In addition, however, a number of muscles belonging to the group occur in connection with the ribs.

1. Intercostales Externi (Fig. 537).

Attachments.—The external intercostal muscles are eleven in number, stretching across all the intercostal spaces from the lower border of one rib to the upper border of the next. The fibres, which are largely interspersed with strands of connective tissue, are directed downward and forward, and form in each intercostal space a sheet which extends in the upper spaces from the tubercle of the rib to the junction of the rib with its costal cartilage and in the lower spaces is continued upon the cartilages. The interval between the medial borders of the upper muscles and the border of the sternum is occupied by a sheet of connective tissue known as the *external intercostal fascia* or *anterior intercostal aponeurosis*.

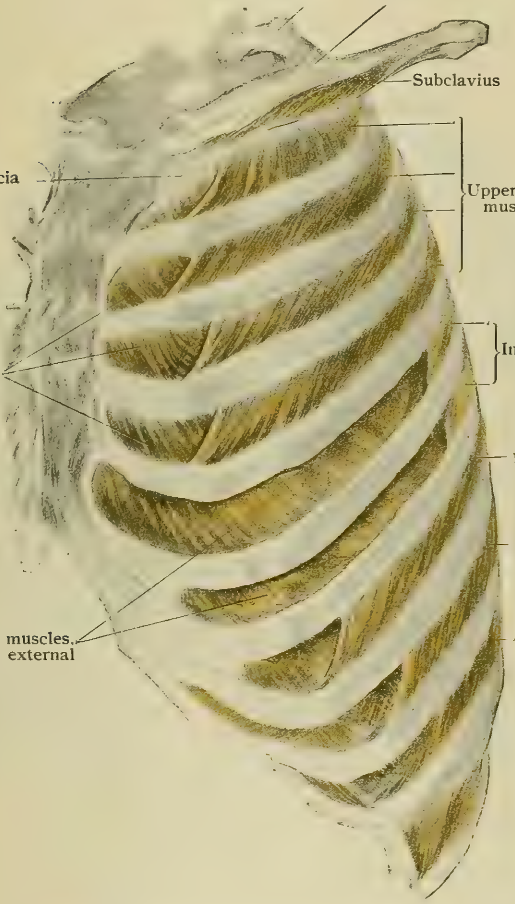
Nerve-Supply. By the anterior divisions (intercostal nerves) of the thoracic nerves.

Action.—To draw the ribs upward.

2. Intercostales Interni (Fig. 537).

Attachments.—The internal intercostals lie immediately beneath the external and, like these, extend across each of the intercostal spaces. The fibres have a direction almost at right angles to those of the external intercostals, being directed obliquely downward and inward from the lower border of one rib and its costal cartilage to the upper border of the next. The muscle-sheets so formed extend from the medial extremity of each intercostal space as far back as the angles of the ribs, becoming there continuous with an *internal intercostal fascia* or *posterior intercostal*

Fig. 537.



Dissection of thoracic wall of left side, showing intercostal muscles and fasciæ.

aponeurosis which continues backward to the tubercles of the ribs. The medial fibres of the muscles of the lower two intercostal spaces become continuous with the upper portion of the internal oblique muscle of the abdomen.

Nerve-Supply.—The anterior divisions (intercostal nerves) of the thoracic nerves.

Action.—To draw the ribs upward.

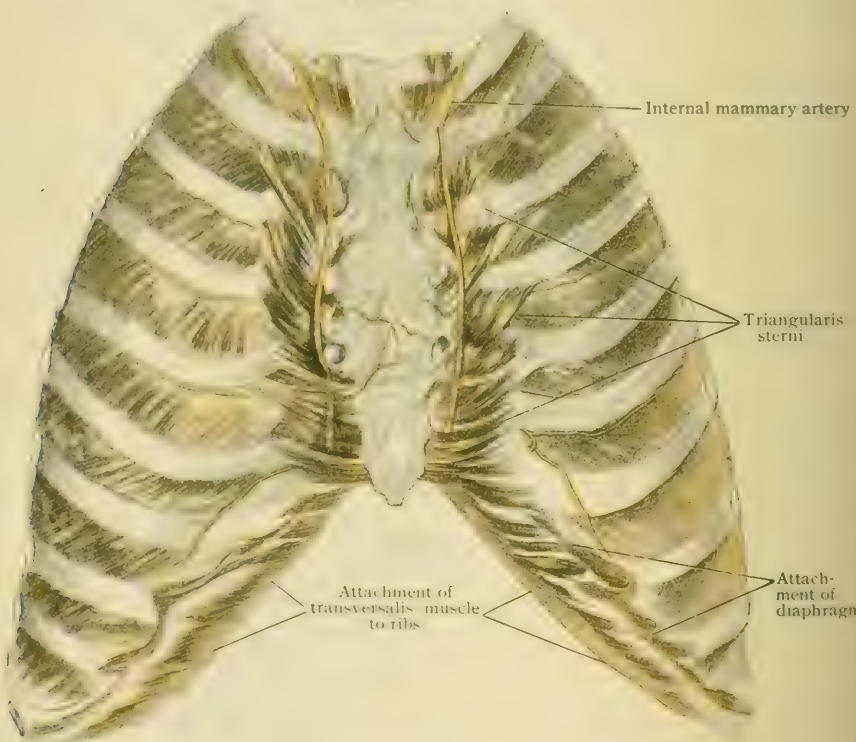
The Subcostal Muscles.—Posteriorly the fibres of the various internal intercostals do not confine themselves to a single intercostal space, but extend downward to the next space below, spreading out in the muscle-sheet of that space. These fibres, which vary greatly in the extent of their development, form what are termed the subcostal muscles.

3. Triangularis Sterni (Fig. 538).

Attachments.—The triangularis sterni (**m. transversus thoracis**) forms a thin sheet situated upon the posterior surface of the medial portion of the anterior thoracic wall. It *arises* at one edge by a series of slips from the costal cartilages of the second or third to the sixth or seventh rib; the upper fibres are directed obliquely downward and medially and the lower ones transversely to be *inserted* by a thin, flat tendon to the sides of the lower portion of the sternum and to the xiphoid process. The lower fibres of the muscle are practically continuous with those of the transversus abdominis.

Nerve-Supply.—By the anterior divisions (intercostal nerves) of the second or third to the sixth or seventh thoracic nerve.

Fig. 538.



Dissection of anterior thoracic wall from behind, showing triangularis sterni and intercostal muscles.

Action.—To draw downward the anterior portions of the ribs and so assist in expiration.

Relations.—The internal mammary vessels pass downward upon the anterior surface of the muscle, separating it from the fibres of the internal intercostals.

4. Levatores Costarum (Fig. 521).

Attachments.—The levatores costarum form a series of thin triangular muscles which *arise* from the transverse processes of the seventh cervical and all the thoracic vertebræ except the twelfth. They are directed downward and laterally to be *inserted* into the posterior surface of the next succeeding rib (*levatores costarum breves*) between the tubercle and the angle, some of the fibres of the lower muscles passing over a rib to be *inserted* into the next but one below (*levatores costarum longi*).

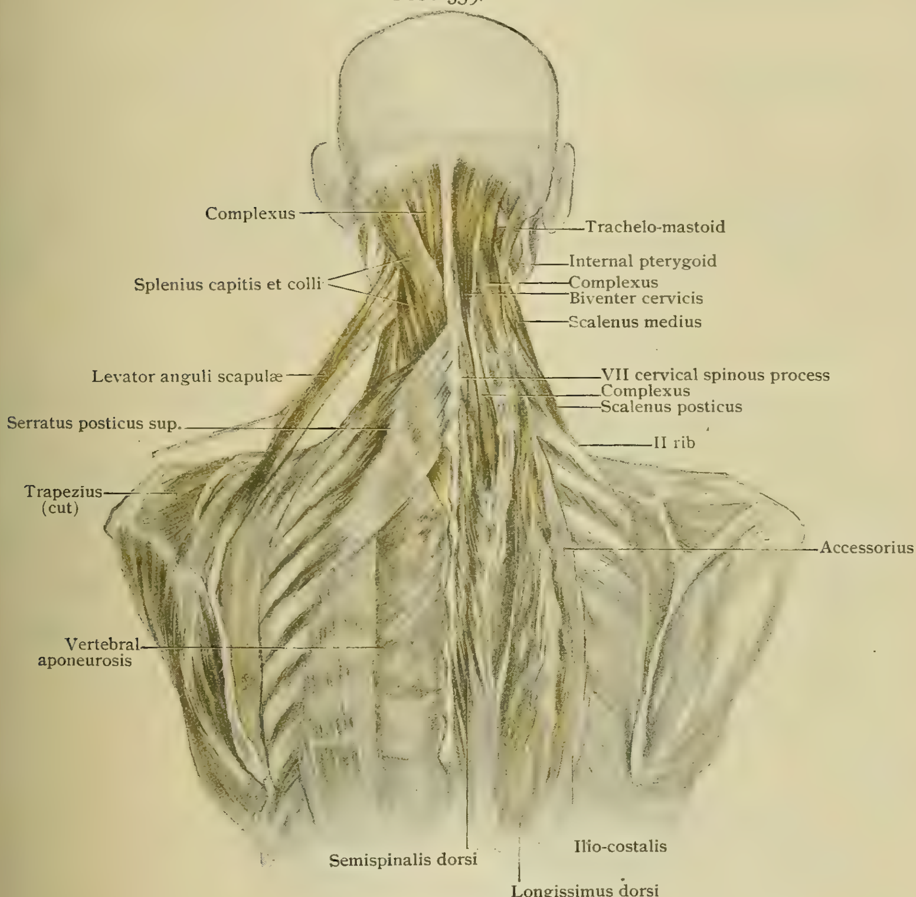
Nerve-Supply.—From the anterior divisions of the eighth cervical and the first to the eleventh thoracic nerves.

Action.—To assist in drawing the ribs upward. Acting from the ribs, they will assist in bending the spinal column backward and laterally towards the same side and in rotating it towards the opposite side.

5. Serratus Posticus Superior (Fig. 539).

Attachments.—The superior posterior serratus is a quadrangular, flat muscle which *arises* by a flat tendon from the lower part of the ligamentum nuchæ and from the spinous processes of the seventh cervical and upper two or three thoracic ver-

Fig. 539.



Dorsal, cervical, and thoracic muscles.

tebræ. Its fibres are directed downward and laterally to be *inserted* into the outer surface of the second to the fifth ribs, lateral to their angles.

Nerve-Supply.—From the anterior divisions of the first to the fourth thoracic nerves.

Action.—To raise the ribs to which it is attached and accordingly assist in inspiration.

6. Serratus Posticus Inferior (Fig. 559).

Attachments.—The inferior posterior serratus *arises* by a broad but thin tendon from the posterior layer of the lumbo-dorsal fascia from about the level of the second lumbar to that of the tenth or eleventh thoracic vertebra. Its fibres are

directed upward and laterally and are *inserted* into the outer surfaces of the lower four ribs.

Nerve-Supply.—From the anterior divisions of the ninth to the twelfth thoracic nerves.

Action.—To draw the ribs to which it is attached downward and outward. The muscle contracts during inspiration and assists in this act by counteracting the tendency which the costal part of the diaphragm has to expend a portion of its contraction in drawing the lower ribs upward and inward.

Variations.—Variations in the extent of their origin are not uncommon in both the posterior serrati. Stretching between them there is an aponeurosis, termed the *vertebral aponeurosis*, which represents the degenerated portion of a large muscle-sheet present in the lower mammalia, of which the two posterior serrati are the persistent upper and lower portions.

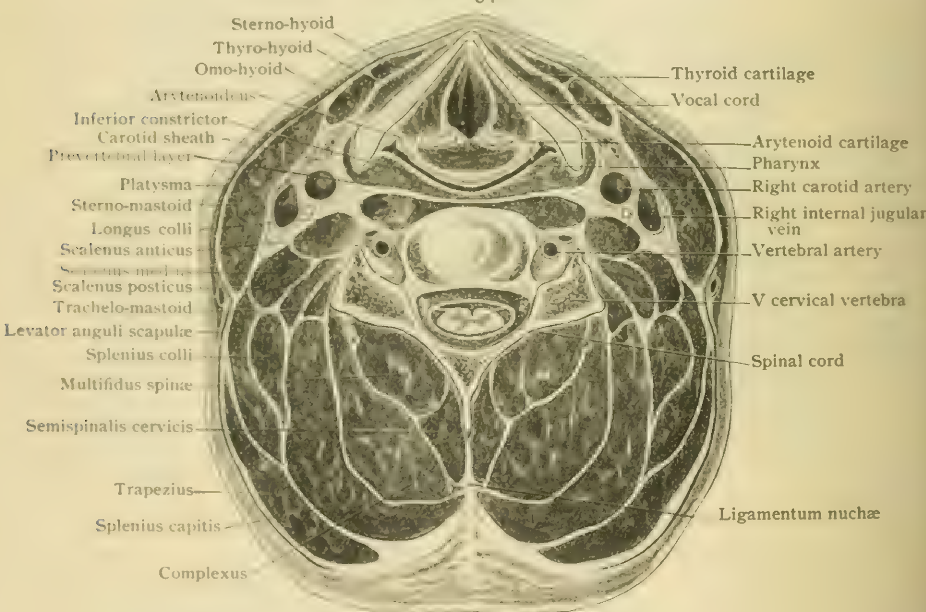
(c) THE HYPOSKELETAL MUSCLES.

The hyposkeletal group of muscles is practically unrepresented in the thoracic region.

THE CERVICAL MUSCLES.

The Deep Cervical Fascia.—The deep cervical fascia (**fascia colli**) is a well-marked sheet of connective tissue which lies beneath the platysma and forms a complete investment for the neck region, giving off from its deeper surface numerous thin lamellæ which surround the various structures of the neck region. Pos-

FIG. 540.



Section across neck at lower border of fifth cervical vertebra.

teriorly the fascia is attached to the ligamentum nuchæ and, traced laterally, it is found to divide into two layers which enclose the trapezius and, uniting again at its outer border, are continued forward over the posterior triangle of the neck to the lateral border of the sterno-cleido-mastoid, where it again divides into two layers to enclose that muscle. The two layers again unite at the medial border of the muscle and are continued over the anterior triangle of the neck to the median line, where the fascia becomes continuous with that of the opposite side.

This is the *superficial layer* of the deep cervical fascia. Above it is attached to the superior nuchal line and the mastoid process, whence it is continued along

the greater cornu and body of the hyoid bone, to which it is firmly attached, and where it becomes continuous above with the deep fascia of the submental region. This fascia covers in the anterior belly of the digastric, the mylo-hyoid, and the submaxillary gland, and is attached above to the lower border of the mandible, where it becomes continuous with the parotideo-masseteric fascia.

Below the cervical fascia ends over the anterior surface of the clavicle, and, more medially, in the interval between the lower portions of the two sterno-cleido-mastoid muscles, it splits into two lamellæ, enclosing what is termed the *spatium suprasternale* or *space of Burns*. Both the lamellæ pass down to be attached to the upper part of the manubrium sterni, so that the suprasternal space is completely closed. It contains some fatty tissue, usually some lymphatic nodes, and the lower portions of the anterior jugular veins ; a diverticulum from it is prolonged laterally behind the insertion of the sterno-cleido-mastoid along each vein as it passes towards its point of union with the subclavian vein.

From the under surface of this superficial layer a deeper or *middle layer* is given off at the sides of the neck, and, passing forward, assists in the formation of the sheath for the carotid artery and internal jugular vein, and then divides to enclose the omo-hyoideus and the other depressors of the hyoid bone, a special thickening of it extending downward from the intermediate tendon of the omo-hyoid to the clavicle. Above, the middle layer is attached to the greater cornu and body of the hyoid bone along with the superficial layer, but below it is continued down into the thorax in front of the œsophagus and trachea and becomes lost upon the upper part of the pericardium.

A third or *deep layer* of the cervical fascia, also termed the *prevertebral fascia*, is given off from the under surface of the superficial layer about on the line of the transverse processes of the vertebræ. It passes almost directly inward over the scalene and hyposkeletal muscles of the neck, enclosing the cervical portion of the sympathetic trunk and contributing to the formation of the carotid sheath. It unites with the corresponding layer of the opposite side over the bodies of the vertebræ. This fascia is continued downward into the thorax in front of the vertebral column and above it extends to the base of the skull. Towards the median line in its upper part it is separated from the pharyngeal portion of the fascia bucco-pharyngea by some loose areolar tissue which occupies the so-called *retro-pharyngeal space*. This is continued downward in the loose tissue surrounding the œsophagus, but is bounded laterally by the union of the pharyngeal and prevertebral fasciæ.

The *carotid sheath* is formed by the union of portions from the middle and deep layers of the cervical fascia. It forms an investment for the common carotid artery, the internal jugular vein, and the vagus nerve.

(*a*) THE RECTUS MUSCLES.

1. Sterno-hyoideus.
2. Omo-hyoideus.
3. Sterno-thyroideus.
4. Thyro-hyoideus.
5. Genio-hyoideus.

1. Sterno-Hyoideus (Fig. 541).

Attachments.—The sterno-hyoid is a flat band-like muscle situated in the front of the neck close to the median line. It *arises* from the posterior surface of the sternal end of the clavicle and from the manubrium sterni and passes upward to be *inserted* into the lower border of the body of the hyoid bone. A mucous bursa, more constant in the male than in the female, usually occurs beneath the upper part of the muscle, resting upon the hyo-thyroid membrane near the median line and immediately below the hyoid bone.

Nerve-Supply.—From the first, second, and third cervical nerves, through the ansa hypoglossi.

Action.—To draw the hyoid bone downward.

Variations.—The sterno-hyoid may arise entirely from the clavicle or it may extend its origin to the cartilage of the first rib. It is often divided transversely by a tendinous band which may occur either in its lower part on a line with the intermediate tendon of the omo-hyoid or, more rarely, in its upper part on a level with the insertion of the sterno-thyroid.

2. Omo-Hyoideus (Fig. 541).

Attachments.—The omo-hyoid is a long, flat muscle consisting of two bellies united by an intermediate tendon. The *inferior belly arises* from the lateral portion of the superior border and the superior transverse ligament of the scapula, and is directed forward, medially, and slightly upward to terminate in the intermediate tendon. This lies behind the clavicular portion of the sterno-cleido-mastoid, and is enclosed by the middle layer of the deep cervical fascia, a specially thickened portion of which binds it down to the posterior surface of the clavicle and to the first rib. The *superior belly arises* at the medial end of the intermediate tendon and passes upward and slightly medially to be *inserted* into the lower border of the hyoid bone, lateral to the sterno-hyoid.

Fig. 541.

Muscles of the neck; larynx has been drawn forward.

Nerve-Supply.—From the first, second, and third cervical nerves, through the ansa hypoglossi.

Action.—To draw downward the hyoid bone. Acting from above, it will assist slightly in drawing the scapula upward. This muscle may also act as a tensor of the cervical fascia, thereby preventing undue pressure on the great vessels of the neck.

Relations.—At its attachment to the scapula the inferior belly is covered by the trapezius and the muscle is crossed in the middle part of its course by the sterno-cleido-mastoid. The inferior belly is in relation posteriorly with the scalene muscles and the roots of the brachial plexus and sometimes with the third portion of the subclavian artery, the transversalis colli and suprascapular arteries, and the suprascapular nerve. The superior belly crosses the common carotid artery and the internal jugular vein at the level of the cricoid cartilage.

Variations.—The omo-hyoid and the sterno-hyoid are derived from a muscular sheet which, in the lower vertebrates, invests the anterior portion of the neck region, lying beneath the platysma. This sheet is represented in man by the two muscles and the middle layer of the deep cervical fascia. The omo-hyoid or one or other of its bellies may be absent, or, on the other hand, an accessory omo-hyoid may be developed. The superior belly not infrequently fuses more or less completely with the sterno-hyoid and the inferior belly has sometimes a clavicular origin. Occasionally the band which binds the intermediate tendon to the clavicle remains muscular, and, uniting at the tendon with the superior belly, produces what has been termed the *cleido-hyoideus.*

3. Sterno-Thyroideus (Fig. 541).

Attachments.—The sterno-thyroid is a band-like muscle which lies immediately beneath the sterno-hyoid. It *arises* from the posterior surface of the manubrium sterni and from the cartilages of the first and second ribs, and passes upward to be *inserted* into the oblique line of the thyroid cartilage.

Nerve-Supply.—From the first, second, and third cervical nerves, through the ansa hypoglossi.

Action.—To draw the larynx downward.

Relations.—Superficially the sterno-thyroid is covered by the sterno-hyoid. Deeply it is in relation with the inferior constrictor of the pharynx, the crico-thyroid muscle, the cricoid cartilage, the lobes of the thyroid gland, the inferior thyroid veins, the trachea, and the common carotid artery, and it crosses the left innominate vein.

Variations.—The lower portion of the muscle is often crossed by a tendinous intersection, and frequently some of its fibres are continued directly into the thyro-hyoid muscle. The two muscles of opposite sides are frequently united in the median line, sometimes throughout the greater portion of their length, at other times merely by scattered bundles.

4. Thyro-Hyoideus (Fig. 541).

Attachments.—The thyro-hyoid lies beneath the upper portion of the omo-hyoid. It *arises* below from the oblique line of the thyroid cartilage and is *inserted* above into the lateral portion of the body and into the greater cornu of the hyoid bone.

Nerve-Supply.—From the first and second cervical nerves, by fibres which run with the hypoglossal nerve.

Action.—To draw down the hyoid bone, or, if that be fixed, to draw the larynx upward.

Relations.—As the muscle passes across the hyo-thyroid membrane it covers the superior laryngeal nerve and artery. A bursa, the *b. musculi thyro-hyoidei*, is interposed between the muscle and the upper part of the hyo-thyroid membrane.

Variations.—The thyro-hyoid is often practically continuous with the sterno-thyroid. A bundle of fibres is sometimes to be found passing either from the lower border of the hyoid or from the thyroid cartilage to the lobe, isthmus, or pyramid of the thyroid gland. It is termed the *levator glandulæ thyroideæ*, under which name are also comprised fibres which are extensions of the inferior constrictor of the pharynx to the thyroid gland.

5. Genio-Hyoideus (Fig. 497).

Attachments.—The genio-hyoid is the superior portion of the rectus group of muscles. It is a rather narrow band which *arises* from the lower genial tubercle of the mandible and extends backward and downward to be *inserted* into the anterior surface of the body of the hyoid bone. It is situated close to the median line, under cover of the mylo-hyoid and immediately beneath the lower border of the genio-glossus.

Nerve-Supply.—From the first and second cervical nerves, by fibres which accompany the hypoglossal.

Action.—If the hyoid bone be fixed, the genio-hyoid depresses the mandible; if the mandible be fixed, it draws the hyoid bone forward and upward.

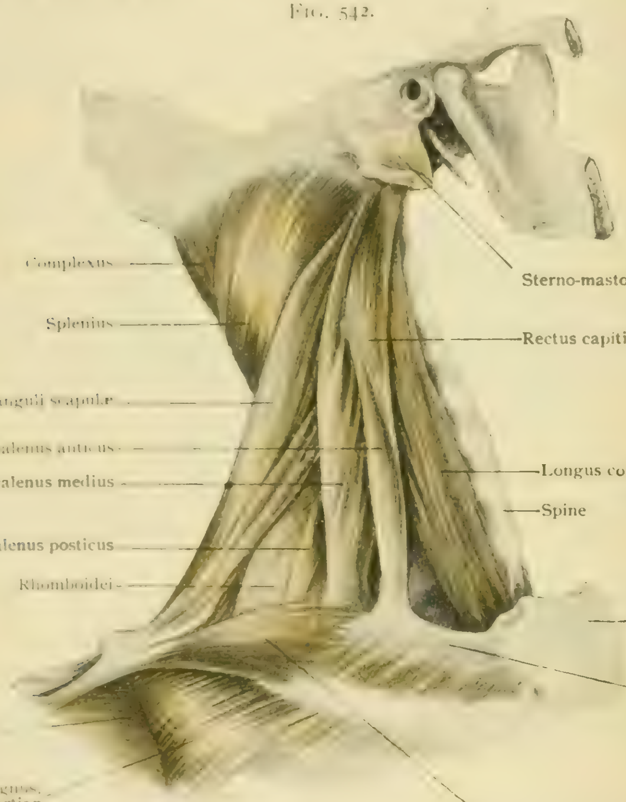
4. THE OBLIQUUS MUSCLES.

1. Scalenus anticus.
2. Scalenus medius.
3. Scalenus posticus.
4. Rectus capitis lateralis.
5. Intertransversales anteriores.

1. Scalenus Anticus (Fig. 542).

Attachments.—The anterior scalene (**m. scalenus anterior**) *arises* by four tendinous slips from the anterior tubercles of the transverse processes of the third to the sixth cervical vertebræ. The four slips unite to form a rather flat muscle which extends downward and forward to be *inserted* into the scalene tubercle on the upper surface of the first rib.

Fig. 542.



Dissection of right side of neck showing scalene and adjacent muscles.

Nerve-Supply.—By branches from the fourth, fifth and sixth cervical nerves.

Action.—To bend the neck forward and to the same side and to rotate it to the opposite side. If the cervical vertebræ be fixed, it will then raise the first rib, assisting in inspiration.

Relations.—The anterior scalenus lies in front of the roots of the brachial plexus, and near its insertion it passes over the second portion of the subclavian artery and under the subclavian vein. The phrenic nerve rests upon its anterior surface during its course down the neck.

2. Scalenus Medius (Figs. 541, 542).

Attachments.—The middle scalene is situated behind the scalenus anterior. It *arises* by six or seven tendinous slips from the transverse processes of the lower six or of all the cervical vertebræ and extends downward and outward to be *inserted*

into the upper surface of the first rib, behind the groove for the subclavian artery. Some fibres of the muscle may extend across the first intercostal space to be inserted into the outer surface of the second rib.

Nerve-Supply.—By branches from the anterior divisions of the cervical nerves.

Action.—To bend the neck laterally, or, if the cervical vertebræ be fixed, to raise the first rib, assisting in inspiration.

Relations.—As the middle scalene passes downward to its insertion it diverges from the scalenus anterior, so that a triangular interval exists between the two muscles through which the subclavian artery and the brachial plexus pass, these structures lying in front of the insertion of the scalenus medius.

3. Scalenus Posticus (Fig. 542).

Attachments.—The posterior scalene (**m. scalenus posterior**) lies immediately behind the scalenus medius and anterior to the ilio-costalis cervicis. It *arises* by two or three tendinous slips from the transverse processes of the lower two or three cervical vertebræ and passes downward and laterally to be *inserted* into the outer surface of the second rib.

Nerve-Supply.—From the anterior divisions of the lower three cervical nerves.

Action.—To bend the neck laterally, or, if the cervical vertebræ be fixed, to raise the second rib.

Variations of the Scalene Muscles.—There is not a little variation in the extent of the upper attachments of the scalene muscles, the origins being increased or, more usually, diminished in number. A certain amount of fusion may also occur, especially between the medius and posterior, so that it is not always possible to distinguish these two muscles. Occasionally the subclavian artery perforates the lower portion of the anterior scalene, and the portion so separated may form a distinct muscle, the *scalenus minimus*, which lies in the interval between the anterior and middle scalenus, and is attached above to the transverse processes of the sixth or the sixth and seventh cervical vertebræ and below to the upper surface of the first rib and to the dome of the pleura.

A muscle occasionally occurs between the upper part of the pectoralis major and the upper external intercostals, from both of which it is separated by a lamella of areolar tissue. It is termed the *supracostalis*, and takes its origin from the first rib and sometimes also from the fascia which covers the anterior scalene, and passes downward to be inserted into the outer surface of the third and fourth ribs, sometimes attaching also to the second rib and sometimes descending as low as the fifth. It has been regarded as an aberrant portion of the pectoralis major or rectus abdominis, but it seems to be more probably a portion of the obliquus musculature and is apparently related to the scaleni.

4. Rectus Capitis Lateralis.

Attachments.—The rectus capitis lateralis is a short, flat muscle which *arises* from the transverse process of the atlas and is *inserted* into the inferior surface of the jugular process of the occipital bone.

Nerve-Supply.—From the suboccipital nerve.

Action.—To bend the head laterally.

5. Intertransversales Anteriores.

Attachments.—The anterior intertransversales are a series of small muscles which pass between the anterior tubercles of the transverse processes of the cervical vertebræ.

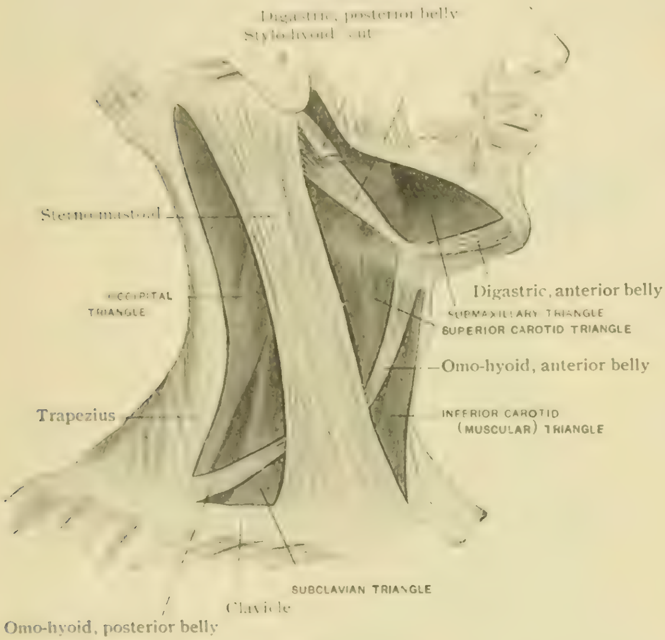
Nerve-Supply.—From the anterior divisions of the cervical nerves.

Action.—To bend the head laterally.

The Triangles of the Neck.—The sterno-cleido-mastoid muscle, on account of its position somewhat superficial to the remaining muscles of the neck, serves to divide that region into two triangular areas which are of considerable importance from the stand-point of topographic anatomy.

One of these triangles, the *posterior*, is bounded by the lateral border of the upper part of the trapezius behind and by the lateral border of the sterno-cleido-mastoid in front, and has for its base the upper border of the clavicle between the insertion of these two muscles. The *anterior triangle* is reversed with respect to the posterior one, having its apex downward and its base above. Its lateral boundary is the medial border of the sterno-cleido-mastoid, its medial boundary is the median line of the neck, and its base is formed by the lower border of the mandible and a line extending horizontally backward from the angle of the mandible to the mastoid process.

Fig. 543.



Triangles of neck.

Each of these two triangles is again divisible into subordinate triangles by the muscles which cross them. Thus the posterior triangle is divided by the inferior belly of the omo-hyoid, which crosses it obliquely, into an upper or *occipital triangle* and a lower or *subclavian triangle*, while the anterior triangle is divisible into three triangles by the superior belly of the omo-hyoid and the posterior belly of the digastric. The lowest of these triangles, termed the *muscular* or *inferior carotid triangle*, has its base along the median line and its apex directed laterally, its sides being formed by the sterno-cleido-mastoid below and the superior belly of the omo-hyoid above. The *superior carotid triangle* has its base along the upper part of the sterno-cleido-mastoid and its apex directed medially; its sides are formed by the superior belly of the omo-hyoid below and the posterior belly of the digastric above. Finally, the *submaxillary* or *digastric triangle* is the basal portion of the original anterior triangle, and is bounded below by the two bellies of the digastric muscle and above by the line of the lower border of the mandible and its continuation posteriorly to the sterno-mastoid muscle.

(*c*) THE HYPOSKELETAL MUSCLES.

1. Longus colli. 2. Rectus capitis anticus major.
3. Rectus capitis anticus minor.

1. Longus Colli (Fig. 544).

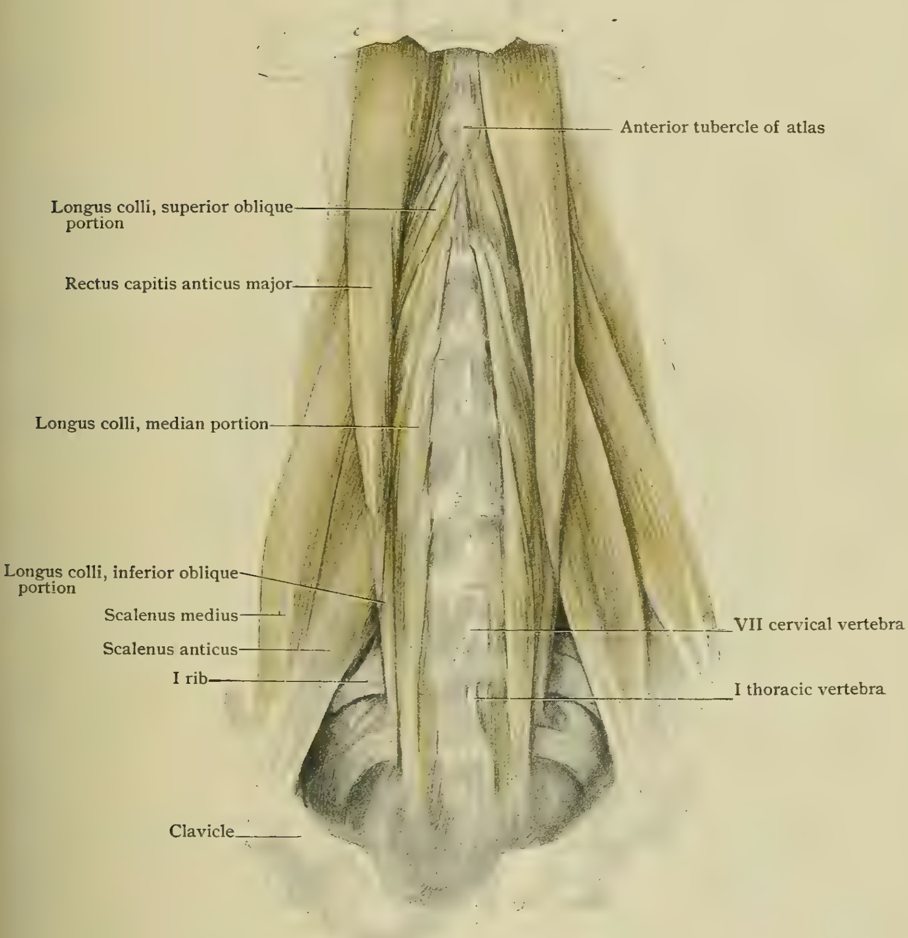
Attachments.—The longus colli forms an elongated triangular band whose base is towards the median line and the wide-angled apex directed laterally. It may be regarded as consisting of three portions. The *medial portion* consists of fibres which *arise* from the bodies of the upper three thoracic and lower two cervical vertebræ, forming a muscular band which is *inserted* into the bodies of the three or four upper cervical vertebræ, the slip to the atlas being inserted into its anterior tubercle. From the lower part of the medial portion slips are given off which constitute the *inferior oblique portion*, and are *inserted* into the transverse processes of the fifth and sixth, and sometimes also of the fourth and seventh, cervical vertebræ.

And, finally, the *superior oblique portion* is formed by slips *arising* from the transverse processes of the sixth to the third cervical vertebræ and joining the upper part of the medial portion.

Nerve-Supply.—From the anterior divisions of the second, third, and fourth cervical nerves.

Action.—To bend the neck ventrally and laterally.

FIG. 544.



Deep dissection of neck, showing prevertebral muscles.

2. Rectus Capitis Anticus Major (Fig. 544).

Attachments.—The rectus capitis anticus major (**m. longus capitis**) partly covers the upper part of the longus colli. It *arises* by four tendinous slips from the transverse processes of the third to the sixth cervical vertebræ, and passes directly upward to be *inserted* into the basilar portion of the occipital bone, lateral to the pharyngeal tubercle.

Nerve-Supply.—From the anterior divisions of the second, third, and fourth cervical nerves.

Action.—To flex the head and rotate it slightly towards the opposite side.

3. Rectus Capitis Anticus Minor.

Attachments.—The rectus capitis anticus minor (**m. rectus capitis anterior**) is a short, flat muscle which *arises* from the anterior surface of the lateral mass of the atlas and is directed obliquely upward and medially to be *inserted* into the basilar portion of the occipital bone, immediately behind the insertion of the longus capitis.

Nerve-Supply.—By the first cervical (suboccipital) nerve.

Action.—To flex the head.

PRACTICAL CONSIDERATIONS: THE NECK.

The skin of the front and sides of the neck is thin and movable. The platysma myoides is closely connected to it by the thin superficial fascia. The edges of wounds transverse to the fibres of that muscle are therefore often inverted.

In the region of the nape of the neck the skin is thicker and much more closely adherent to the deep fascia; it is poorly supplied with blood; hair-follicles and sebaceous glands are numerous; it is frequently exposed to minor traumatisms and to changes of surface heat, and is often at a lower temperature than the parts immediately above, which are covered with hair, or than those directly below, which are protected by clothing; the nerve-supply is abundant. For these reasons furuncles and carbuncles are of common occurrence and are apt to be exceptionally painful.

The subcutaneous ecchymosis which follows fracture through the posterior cerebral fossa first appears anterior to the tip of the mastoid and spreads upward and backward on a curved line; the blood is prevented from reaching the surface more directly by the cervical fascia, and therefore goes laterally in the intermuscular spaces, being directed towards the mastoid tip by the posterior auricular artery.

In the submaxillary region the looseness of the skin makes it available for plastic operations on the cheeks and mouth. In the submental region the accumulation of subcutaneous adipose tissue seen in stout persons gives rise to the so-called "double chin." In both the latter regions (covered by the beard in men) furuncles and sebaceous cysts are common.

The surgical relations of the fascia of the neck can best be understood by reference to a horizontal section at the level of the seventh cervical vertebra (Fig. 545).

The superficial layer (*a, a'*) will then be seen to envelop the entire neck. Posteriorly it is attached between the external occipital protuberance and the seventh cervical spinous process to the ligamentum nuchæ; anteriorly it is interlaced with the same layer of fascia from the other side of the neck; superiorly between the external occipital protuberance and the middle of the chin it is attached on each side to the superior curved line of the occipital bone, the mastoid, the zygoma, and the lower jaw; inferiorly between the seventh spine and the suprasternal notch it is attached on each side to the spine of the scapula, the acromion, the clavicle, and the upper edge of the sternum. After splitting to enclose the trapezius and covering in the posterior triangle, this fascia divides again at the hinder border of the sterno-cleido-mastoid. The superficial layer continues over the surface of that muscle, covers in the anterior triangle, and blends with its fellow of the opposite side.

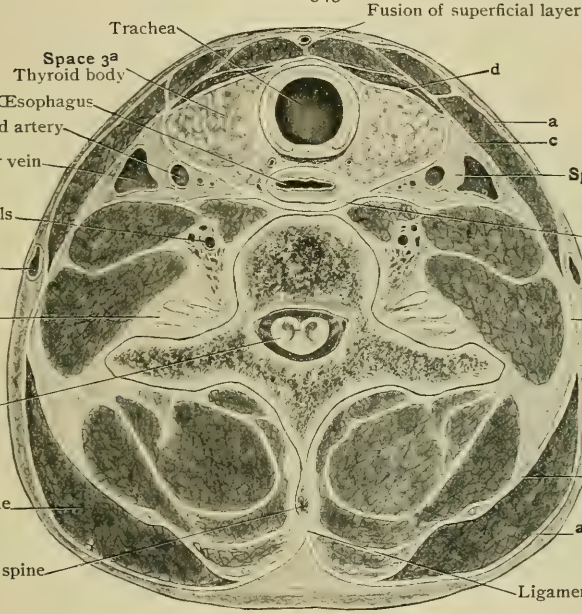
From its under surface, after reaching the sterno-mastoid, the deeper layer gives off from behind forward (*b*) a process—prevertebral fascia—which begins near the posterior border of the sterno-mastoid, passes in front of the scalenus anticus, the phrenic nerve, the sympathetic nerve, and the longus colli muscle, and behind the great vessels, the pneumogastric nerve, and the œsophagus to the front of the base of the skull and the bodies of the cervical vertebræ. In the mid-line this descends behind the gullet into the thorax. At the sides of the neck it helps to form the posterior wall of the carotid sheath, spreads out over the scalene muscles, and passes down in front of the subclavian vessels and the brachial plexus, until it dips beneath the clavicle. It is then applied closely to the under surface of the costo-coracoid membrane and splits to become the sheath of the axillary vessels. A second process (*c*), leaving the sterno-mastoid more anteriorly, aids in forming the anterior wall of the carotid sheath, and joins the preceding layer just internal to the vessels. It is

usually described as part of (d) a process—tracheal—which leaves the sterno-mastoid nearer its anterior border, and, running behind the sterno-hyoid and sterno-thyroid muscles, descends in front of the trachea and the thyroid gland to become connected with the fibrous layer of the pericardium.

The adhesion of the deep fascia to the blood-vessels, by preventing contraction and collapse of their walls, favors hemorrhage and increases the risk of the entrance of air into divided veins.

Tracing the layers of fascia vertically and from the surface inward, it will be useful to remember that the superficial layer (a, Fig. 546) passes to the top of the sternum (sending a slip to be attached to its posterior border) and to the clavicle. The second layer (b) descends behind the depressors and in front of the thyroid gland and trachea to merge into the pericardium, and farther out to form a sheath for the omo-hyoid and for the subclavian vein, and is lost in the sheath of the subclavius.

FIG. 545.



Section across neck at level of seventh cervical vertebra.

This relation of the omo-hyoid is of value in enabling that muscle, when the hyoid is fixed, to increase the tension of this layer of fascia, and thus hold open and prevent atmospheric pressure upon the walls of the vessels—especially the veins—and the soft parts (including the pulmonary apices) at the base of the neck. Hilton uses this function of the muscle—which connects it with the act of respiration—to illustrate the precision of the nerve-supply to muscles generally. The omo-hyoid arises in close proximity to the suprascapular notch, and therefore to the suprascapular nerve. Yet it never receives a filament from that nerve, but is supplied by the cervical nerves to bring it in relation to the movements of the other neck muscles, is connected with the hypoglossal to associate it with the movements of the tongue, and with the pneumogastric to enable it to act as above described during forced respiration, when the rush of air into the thorax might otherwise cause harmful increase of atmospheric pressure in the lower cervical or supraclavicular region.

The pretracheal layer is found between the depressors and the trachea passing down to its pericardial insertion. Hilton thus explains this insertion: "The pericardium is most intimately blended with the diaphragm, distinctly identified with it, and capable of being acted upon by it at all times. It is also attached above to the deep cervical fascia. It is thus kept tense by the action of the respiratory muscles in the neck attached to the cervical fascia above and the diaphragm attached to it

below; or, in other words, these two muscular forces are acting on the interposed pericardium in opposite directions, and so render it tense and resisting. And the special object, no doubt, of this piece of anatomy is that during a full inspiration, when the lungs are distended with air and the right side of the heart gorged with blood from a suspension of respiration, the heart should not be encroached upon by the surrounding lungs."

The prevertebral layer (*c*, Fig. 546) lying between the œsophagus and spine passes in the mid line directly into the posterior mediastinum; laterally—beyond the scalenus anticus—it aids in forming the sheath of the subclavian vessels and accompanies them into the axilla.

Another way of elucidating the practical effect of the somewhat complex distribution of the cervical fascia is to regard the three chief layers—superficial, middle, and deep—as dividing the neck into four anatomical spaces (Tillaux).

1. Subcutaneous (Space 1, Fig. 545): between the skin and the superficial layer. The most important structure in this space is the external jugular vein, which perforates the fascia just above the middle of the clavicle.

2. Intra-aponeurotic (Space 2, Fig. 546): between the superficial and middle (sterno-clavicular) layers. This space does not exist in fact at the summit of the neck where the two layers are one, but at the base its depth is equal to the thickness of the sternum. It may be continuous with the space left at the top of the sternum between the two leaflets of the superficial layer attached to the anterior and posterior borders of the sternum, — Grüber's "suprasternal intra-aponeurotic space," "Burns's space." It contains fat and lymphatic glands, the sternal head of the sterno-mastoid, and the anterior jugular veins. It is not infrequently the seat of abscess.

Fig. 546.

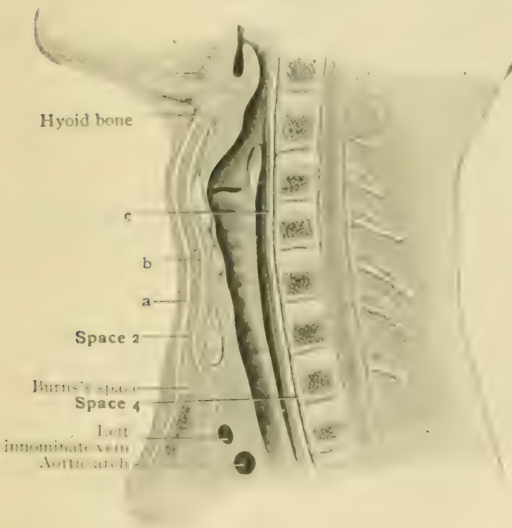


Diagram showing relations of cervical fascia in longitudinal section.

3. Visceral (Space 3 = 3*a* + 3*b*, Fig. 545): between the pretracheal and prevertebral layers. This includes all the principal structures of the neck. As it communicates directly with the thorax and axilla, suppuration may travel in those directions. It is divided into minor spaces (3*a* and 3*b*) by a layer of fascia coming from the under surface of the sterno-mastoid muscle and by the bucco-pharyngeal fascia, a thin layer that comes off from the prevertebral fascia where it leaves the carotid sheath, and which lines the constrictors of the pharynx, leaving between it and the layer applied to the spinal column a small but easily distended space—retropharyngeal—in which infection from pharyngeal lesions occasionally occurs.

4. Retrovisceral (Space 4, Fig. 546): the space between the prevertebral fascia and spinal column, including the longus colli and rectus capitis anticus, the sympathetic nerve, etc.

It is obvious in a general way that all infections beneath the middle layer of fascia are more likely to be serious than those superficial to it.

But to summarize in a little more detail the practical relations of the cervical fascia, we may conclude that superficial to the outer layer (*a*, Fig. 545) there might occur from traumatism a wound of the external jugular, or from infection a spreading cellulitis. The space is the seat of superficial phlegmons, which tend to spread under the skin only (Space 1, Fig. 545), and, in the absence of tension, are unattended by throbbing pain or marked constitutional symptoms.

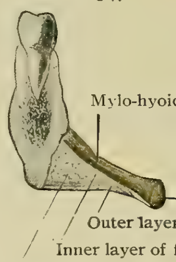
The space between *c* and *b* (3*b*, Fig. 545) is occupied only by the great vessels and the pneumogastric. Infection there—*i.e.*, within the sheath—may mean descending thrombosis from original infection of a cerebral sinus, or may have spread directly through the sheath from infected tracts of cellular tissue outside. Behind *b*, Fig. 545 (retrovisceral space), suppuration is not uncommon as a result of vertebral disease. Direct infection through the pharyngeal wall usually involves the retropharyngeal space. In either case dysphagia and dyspnœa are usual for obvious reasons.

Between *b* and *c*, Fig. 546 (pretracheal and prevertebral layers), abscess would spread most readily along the line of the trachea and in front of the vessels into the superior mediastinum.

In the intra-aponeurotic space (Space 2, Fig. 546) an abscess would probably point superficially, as the fascia in front of it is very thin. If it were influenced by gravity, however, it would follow the hyoid depressors and their intermuscular spaces to the root of the neck, and might enter the superior mediastinum.

Two additional and important spaces are formed by extensions or reduplications of the cervical fascia. That portion of the superficial layer above the level of the angle of the inferior maxilla, and passing from that bone to the zygoma, constitutes the parotid fascia, which on the surface is continuous with that over the masseter, while beneath it becomes thickened to constitute the stylo-maxillary ligament, separating the parotid and submaxillary glands and resisting overaction of the external pterygoid muscle. As the outer fascial investment of the gland is dense and resistant, and as internal to this ligament the inner layer is thinner and weaker than elsewhere,—a positive gap existing between the styloid process and the pterygoid muscle,—suppuration within the gland may result in extension to the retropharyngeal region. It may follow the external carotid downward to the chest, or, as the fascial investment is also incomplete above, may extend upward to the base of the skull, or even into the skull. It sometimes follows the branches of the third division of the fifth nerve through the foramen ovale into the cranium.

Fig. 547.



Portion of frontal section across mandible, showing relations of cervical fascia.

The second space alluded to is formed by that portion of the superficial layer between the jaw and the hyoid bone and in front of the stylo-mandibular ligament. As it passes forward from the latter structure it splits and envelops the submaxillary gland, and becomes firmly attached below to the hyoid and above to the lower jaw externally and the under surface of the mylo-hyoid muscle internally (Fig. 547). Infection—"Ludwig's angina," "submaxillary phlegmon," "deep cervical phlegmon"—in this space, which contains the salivary gland and its attendant lymphatics, is rendered exceptionally grave by the density of these fascial layers. The infecting organisms—usually streptococci—may gain access through a lesion of the floor of the mouth near the frenum, or from an alveolar abscess, or by way of the digastric muscle from a focus of disease in the middle ear. Once established, they, with their secondary products, are forced along the lines of least resistance—by the side of the mylo-hyoid usually—towards the base of the tongue, involving the cellular tissue about the glottis and along the vessels that perforate the fascia, causing infective venous thrombosis and involving the deeper planes of connective tissue. Under the latter circumstances, if tension is not promptly relieved, large vessels may be opened by the necrotic process. Jacobson long ago called attention to the interesting fact that communications between abscesses and deep vessels have usually taken place beneath the cervical fascia and the fascia lata, two of the strongest fasciæ of the body.

Tumors of the neck may originate in any of the diverse structures of that region. It may be mentioned here that their situation above or beneath the cervical fascia is an important factor in determining their mobility, and hence the probable ease or difficulty of their removal. In the latter situation associated pressure-symptoms are common.

Lipoma is frequent; fibroma and enchondroma are occasionally seen in the region of the ligamentum nuchæ; primary carcinoma is rare.

Congenital cysts—"hydroceles"—of the neck are found beneath the deep fascia, usually in the anterior triangle and below the level of the hyoid. They may arise from dilatation of the lymphatic vessels, or, as Sutton suggests, they may originate, as do the cervical air sacs in some monkeys, especially the chimpanzees, by the formation of diverticula from the laryngeal mucous membrane. In any event, they ramify in the various intermuscular spaces, and their complete removal is therefore very difficult.

Branchial cysts and dermoids are not infrequent. They should be studied in connection with the embryology of the region.

Congenital tumor of the sterno-mastoid is a condition resulting from either rupture of muscular fibres or bruising of the muscle against the under surface of the symphysis during delivery. It may be a cause of torticollis.

Torticollis—"wry-neck"—may be due to spasm of the sterno-mastoid either alone or associated with a similar condition of the trapezius, especially the clavicular portion, and often of the scaleni or the complexus. Later there is apt to be secondary contraction of the deep fascia and of the posterior cervical muscles. Tenotomy of the muscle for the relief of this affection is performed at a level just above its sternal and clavicular insertion. The subcutaneous method has been largely discarded in favor of division through an open wound. By the former plan, not only were the anterior, and sometimes also the external, jugular veins endangered, but the cervical space described as "visceral" was occasionally opened, and, if infection occurred, with fatal results from septic cellulitis or pleurisy.

Section of the spinal accessory nerve may be resorted to when the spasm is limited to the sterno-mastoid and trapezius, or of the posterior primary divisions of the first, second, and third cervical nerves when the posterior muscles are involved.

Landmarks.—Athough but few organs belong exclusively to the neck, a great many structures of much diversity, and connecting the trunk and head, pass through it. The "landmarks" will therefore be found in relation to different systems,—vascular, nervous, etc.,—those given here referring chiefly to the muscles and their effect upon surface form.

The mid-line posteriorly has already been described in its relation to the spines of the cervical vertebræ (pages 146–148).

On the sides of the neck the platysma, when in action, produces inconspicuous wrinkling of the skin. Its fibres are in a line from the chin to the shoulder. The sterno-mastoid, running obliquely from the skull to the sternum and clavicle, divides each lateral half of the neck into two triangles. The anterior of these is bounded above by the lower border of the inferior maxilla and a line extending from the angle of that bone to the mastoid process; anteriorly by a straight line between the middle of the chin and the sternum; posteriorly by the anterior border of the sterno-mastoid. Its apex is at the middle of the upper edge of the manubrium. The posterior triangle is bounded posteriorly by the anterior edge of the trapezius, the hinder edge of the sterno-mastoid in front, and the middle of the clavicle below. Its apex is just behind the mastoid process.

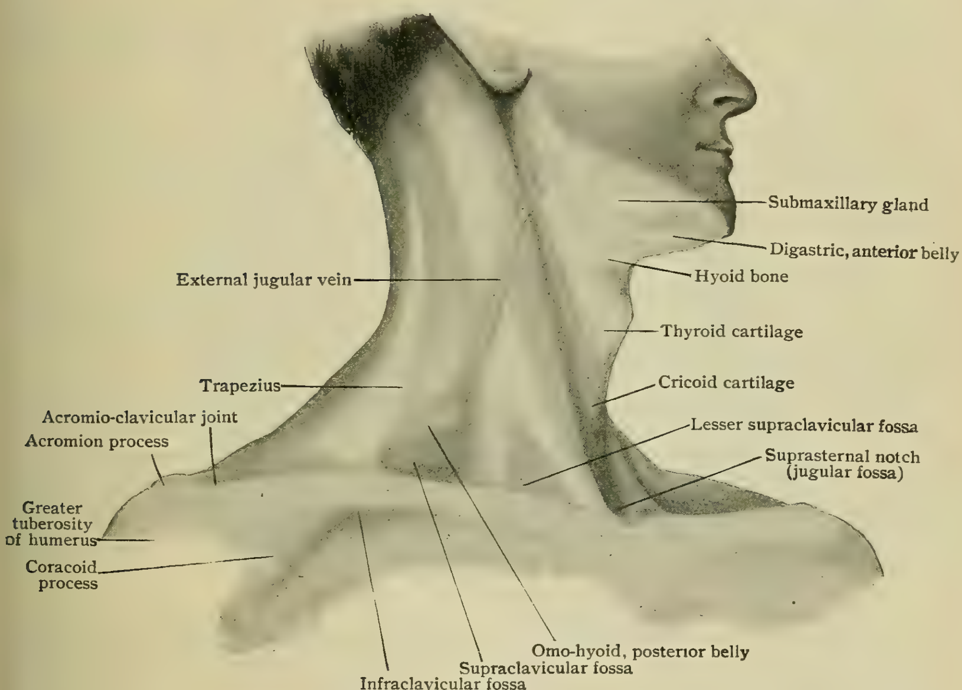
It will be seen that by this—the usual—description those structures lying immediately beneath the sterno-mastoid would be excluded from both triangles. It is customary, however, to include the common carotid and internal jugular vein in the anterior triangle, although they are both under cover of the anterior edge of the sterno-mastoid.

The anterior triangle is divided into three—the superior carotid, the inferior carotid, and the submaxillary—by the digastric muscle and the anterior belly of the omo-hyoid. The posterior belly of the omo-hyoid divides the posterior triangle into a lower or subclavian and an upper or occipital triangle. The structures included within these various triangles will be described in connection with the vessels, nerves, etc.

The dividing line between the two main triangles—the sterno-mastoid—can be both seen and felt if, with the mouth closed, the chin is depressed and the skull is rotated towards the opposite shoulder. The thick, prominent, rounded anterior bor-

der can then be made out from mastoid to sternum, but is more accentuated below, where the sternal head is salient and sharply defined. This thin posterior border may be felt vaguely at the upper part, but cannot be seen. At about the lower third it becomes visible and is continued into the broader and flatter clavicular head. The middle of the muscle is seen throughout most of its length as a fleshy, rounded elevation. Over it, and usually plainly visible, is the external jugular vein, running between the platysma and the deep fascia in a line from the angle of the jaw to the centre of the clavicle. In rest the anterior border is still visible. The position of the muscle on the side towards which the head is turned is indicated by a slight furrow in the skin. The muscles partly overlapped by the sterno-mastoid are, from above downward, the splenius, levator scapulæ, digastric, omo-hyoid, sterno-thyroid, and sterno-hyoid.

FIG. 548.



Surface markings of neck, from living subject.

The interval between the sternal and clavicular heads of the muscle is indicated by a slight depression,—the lesser supraclavicular fossa,—and is bounded below by the upper edge of the inner third of the clavicle. Beneath it, about on a line with the sternal end of the clavicle, lie on the right side the bifurcation of the innominate artery and on the left the common carotid artery.

Between the outer edge of the clavicular head of the sterno-mastoid and the base of the anterior edge of the trapezius is a broad, flat depression,—the supraclavicular fossa,—which is made very evident by shrugging the shoulders, and across which the posterior belly of the omo-hyoid runs and can often be seen and felt in thin persons, especially during inspiration or when the head is turned towards the opposite side (Fig. 548). The line of the muscle is from the suprascapular notch, slightly ascending to the anterior margin of the sterno-mastoid at a level with the cricoid cartilage and then rapidly ascending to the body of the hyoid. Below its

posterior belly run the brachial plexus, which can often be felt and sometimes seen, and, near the clavicle, the subclavian artery.

Farther out the anterior border of the trapezius may be seen passing from the occiput to its insertion at the outer end of the middle third of the clavicle. The triangular interval between it and the posterior border of the sterno-mastoid is filled —from below upward—by the scalenus medius, the levator anguli scapulæ, and the splenius, but none of them is recognizable through the deep fascia.

In the mid-line behind, in addition to the bony points already given (pages 146–148), the line of origin of the trapezii can be seen as a slight elongated depression. None of the deeper muscles can be seen or felt upon the surface.

In the mid-line in front the hyoid bone and its cornua can be felt in the angle between the under surface of the chin and the front of the neck. From the hyoid bone on either side the anterior bellies of the digastric run up towards the symphysis and with the subcutaneous fat give convexity to the submental region. Farther out on this level the submaxillary salivary glands can be felt and often seen.

The thyro-hyoid depression, the prominence of the thyroid cartilage (*pomum Adami*), the crico-thyroid space, the cricoid cartilage, and sometimes the upper rings of the trachea may be felt from above downward. The relations of these parts to important vascular and nervous structures will be considered later.

The sterno-thyroid and sterno-hyoid muscles, while not visible, cover over and obscure the outlines of the trachea, as does also the thyroid isthmus. The thyroid lobes may be felt on each side of the larynx. The average distance from the cricoid to the upper edge of the manubrium is about one and a half inches when the head is erect. In full extension three-quarters of an inch additional can be gained.

The trachea recedes as it approaches the sternum, so that it is fully an inch and a half behind the upper border of the latter. In this position between the two sternal heads of the sterno-mastoid is the deep, V-shaped suprasternal notch (fossa jugularis), the depth of which is noticeably affected by forced respiration, being much increased in obstructive dyspnœa.

All the surface appearances above described differ in different individuals, and vary in the same person in accord with many conditions, as the amount of subcutaneous fat, the muscular vigor and development, the pulmonary capacity, the state of repose or of violent exertion, etc. This should be remembered in looking for landmarks in this region, which is in that respect one of the most variable of the body, and most unlike that of the cranium, which perhaps typifies the other extreme of unchangeability.

DIAPHRAGMA (Fig. 549).

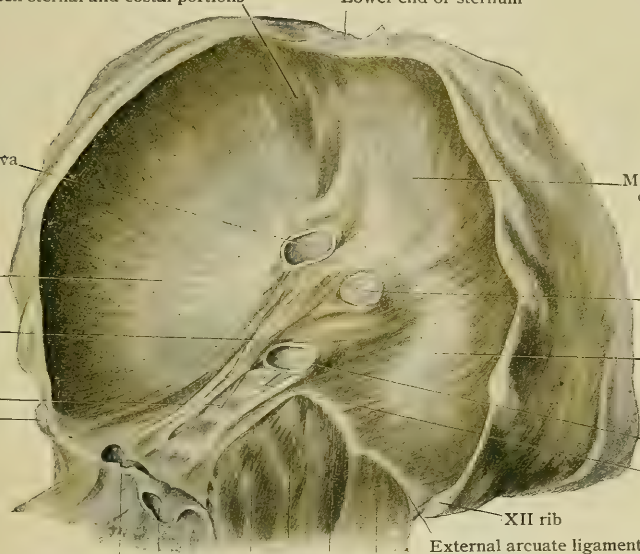
The diaphragm is a dome-shaped muscular sheet which separates the thoracic and abdominal cavities. Notwithstanding its position in the adult, it is a derivative of the cervical myotomes. It represents the upper portion of a structure which is termed in embryology the septum transversum (page 1701), a connective-tissue partition which extends between the ventral and lateral walls of the body and the heart, and serves to convey venous trunks to that organ. Like the heart, when first formed it lies far forward in the uppermost part of the cervical region, but later it descends with the heart until it reaches its final position. As it passes the third and fourth cervical myotomes in its descent, it receives from them some muscle-tissue which eventually forms all the muscle-tissue of the diaphragm, that structure, so far as it is to be regarded as a muscle, being a derivative of the cervical myotomes named.

The diaphragm is a muscular sheet composed of fibres radiating from the lower border of the thorax and from the upper lumbar vertebræ towards a central tendinous area, termed the *centrum tendineum*. According to their origin, the muscle-fibres may be grouped into three portions. The *sternal portion* consists of, usually, two bands which *arise* from the posterior surface of the xiphoid process of the sternum and are separated from one another by a narrow interval filled with connective tissue. Laterally they are separated by a similar interval, through which the superior epigastric artery enters the sheath of the rectus abdominis, from the

costal portion, the fibres of which take their *origin* from the cartilages of the lower six ribs, interdigitating with the origins of the transversalis abdominis. In continuity with the costal part is the *lumbar part*, whose fibres take *origin* (1) from two tendinous arches, the *internal* and *external arcuate ligaments*, which pass over the upper portions of the psoas (**arcus lumbocostalis medialis**) and the quadratus lumborum muscles (**arcus lumbocostalis lateralis**) respectively, stretching between the twelfth rib and the transverse process of the first lumbar vertebra, and (2) by two downward prolongations, the *crura*, from the anterior and lateral surfaces of the upper three or four lumbar vertebræ.

The right crus usually extends somewhat farther downward than the left, whose attachment does not pass below the second or third vertebra. Each crus has been divided into three portions, medial, intermediate, and lateral, which are not, however, always clearly recognizable, although indicated by the passage of certain structures from the thorax to the abdomen. Thus, between the medial and intermediate

FIG. 549.



Diaphragm, viewed from below and the left.

crura the greater splanchnic nerve and the azygos (or hemiazygos) veins pass, while between the intermediate and lateral crura is the sympathetic trunk.

The two crura, as they pass upward, leave between them an opening, the *hiatus aorticus*, which is bridged over by a tendinous band (*median arcuate ligament*) and gives passage to the aorta and thoracic duct. Just behind the posterior margin of the centrum tendineum the crural fibres diverge to surround in a sphincter-like manner the *hiatus œsophageus*, through which pass the œsophagus and the vagus nerves and œsophageal branches from the gastric artery and veins.

The *centrum tendineum*, into which the fibres of the three portions insert, is situated somewhat nearer the anterior than the posterior margin of the diaphragm, so that the fibres of the sternal muscular portion are considerably shorter than the others. It has a trefoil shape, possessing a central and two lateral lobes, the right one of these being perforated by a somewhat quadrate foramen, the *foramen venæ cavæ* (*foramen quadratum*), which transmits the vena cava inferior.

The centrum tendineum forms the centre of the dome of the diaphragm, and from its borders the muscular fibres slope downward towards their insertion, the slope of the crural fibres being much steeper than those of the other portions.

The dome does not, however, form a simple curve, but is divided by a median depression, which traverses it from before backward, into two secondary lateral domes which are unequally developed, that of the right side extending upward as far as the level of the junction of the fourth costal cartilage and rib, while that of the left reaches only to the fifth costo-cartilaginous junction.

Nerve-Supply.—From the third, fourth, and sometimes the fifth cervical nerves, by the phrenic nerves.

Action.—To increase the vertical diameter of the thorax, a contraction of the muscle-fibres depressing the summit of the dome.

Relations.—The upper surface of the diaphragm forms the floor of the thoracic cavity and is in contact with the pleuræ and pericardium, the latter being adherent to the centrum tendineum. Below, the diaphragm is largely invested by peritoneum, and is in relation with the liver, stomach, spleen, kidneys, suprarenal bodies, duodenum, pancreas, inferior vena cava, and the branches of the cœliac artery.

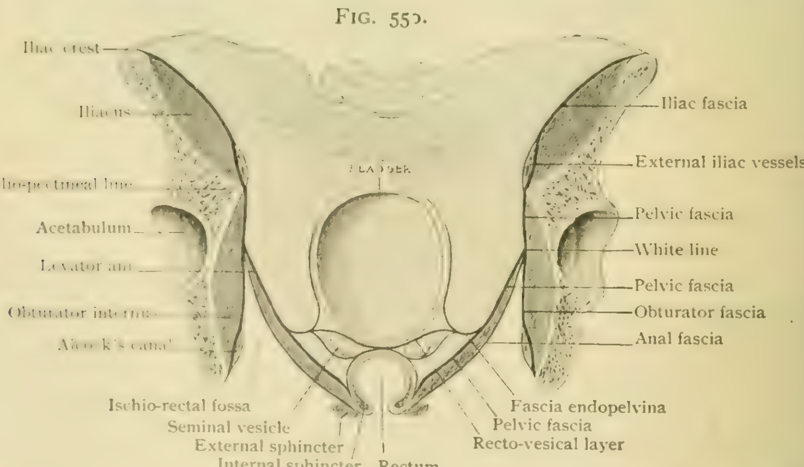
Variations.—Occasionally the diaphragm is incomplete in its posterior portion, a condition which permits the formation of congenital diaphragmatic hernias. Embryologically the posterior portion of the diaphragm is the last to form, and in this fact is probably to be found an explanation of the location of this imperfection and also of the course of the phrenic nerves anterior to the roots of the lungs to reach the earlier formed anterior portion of the diaphragm.

Fibres which arise from the crura and pass to neighboring structures are frequently present. Among the more constant of these are fibres which arise from the inner borders of both crura and pass to the lower portion of the œsophagus, mingled with dense connective-tissue fibres, and others which pass from one crus or the other into the mesentery of the upper part of the jejunum. Probably the *suspensory muscle of the duodenum*, or *muscle of Treitz*, which passes from the left crus to the terminal portion of the duodenum, belongs to this latter group of fibres, although it has been stated to be formed by non-striated muscle-fibres.

THE PELVIC AND PERINEAL MUSCLES.

The ventral portions of the myotomes succeeding the first lumbar and from that as far down as the third (or second) sacral are almost entirely unrepresented in the trunk, being devoted to the formation of the musculature of the lower limb. Below

FIG. 559.



Diagrammatic frontal section through pelvis, showing relations of fascial layers to pelvic wall and floor.

the point mentioned, however, the ventral musculature again appears in the trunk in the pelvic, the perineal, and occasionally the coccygeal region. Owing to the conditions under which it appears, it is not possible to refer the muscles derived from it to the various subdivisions into which the ventral musculature of other regions is divisible, and they will therefore be considered in sequence without any attempt at classification other than regional.

The Pelvic Fascia.—The pelvic fascia is attached above to the promontory of the sacrum and the ilio-pectineal line (**linea terminalis**) of the pelvis, where it

becomes continuous with the iliac fascia. It descends over the surface of the pyriformis and laterally over the upper portion of the obturator internus and the pelvic surface of the pelvic diaphragm. In the upper part of its course over the pelvic diaphragm it is crossed by a curved thickening, the **arcus tendineus**, which is attached behind to the spine of the ischium and passes in front upon the sides of the prostate gland or, in the female, upon the bladder, and is continued thence to the anterior pelvic wall to be attached on either side of the symphysis pubis, a little above its lower border, as a *lateral pubo-prostatic* (*pubo-vesical*) *ligament*. Along this tendinous arch the pelvic fascia gives off a layer which passes inward to the pelvic viscera, and is termed the **fascia endopelvina**. In its anterior portion this forms an investment of the prostate in the male and of the base of the bladder in the female, and its under surface in this region is in contact with, and indeed may be regarded as being fused with, the superior layer of the triangular ligament (page 563). That portion of the layer which intervenes between the prostate (or bladder) and the posterior surface of the body of the pubis forms what is termed the *median pubo-prostatic* (*pubo-vesical*) *ligament*.

The continuation of the pelvic fascia passes downward over the surface of the pelvic diaphragm, and is termed the *superior fascia* of that structure (**fascia diaphragmatis pelvis superior**).

The Obturator Fascia.—From the line along which the pelvic fascia leaves the surface of the obturator internus muscle to pass upon the pelvic diaphragm a sheet of fascia is continued downward over the surface of the obturator internus muscle to be attached below to the tuberosity and ramus of the ischium and the ramus inferior of the pubis. This is the *obturator fascia*.

Along its upper border, nearly corresponding with the arcus tendineus of the pelvic fascia, but lying above this thickening and ending anteriorly farther from the median line, is a similar curved thickening extending from the spine of the ischium, or in some cases from the ilio-pectineal line behind to the posterior surface of the body of the os pubis in front. From this thickening the greater portion of the levator ani muscle arises; it is consequently termed the **arcus tendineus m. levatoris ani**, or more briefly the *white line*. From the line a thin layer of fascia is continued inward upon the under surface of the levator ani, forming what is termed the *anal fascia* (**fascia diaphragmatis pelvis inferior**).

This latter fascia forms the inner and the obturator fascia the outer wall of the ischio-rectal fossa. Near its lower border the obturator fascia splits into two layers to form a canal, the *canal of Alcock*, along which the pudic vessels and nerve pass towards the perineum.

In the above description the term pelvic fascia is applied to the layer of fascia which lines the entire true pelvic cavity,—that is to say, the funnel-shaped cavity included between the pelvic brim and floor. This conception, employed by the German authors, differs somewhat from that usually held by English anatomists, in that the latter restrict the term to that portion of the fascia extending from the ilio-pectineal line to the white line, the continuation downward over the pelvic diaphragm being termed the *recto-vesical fascia*, from which extensions pass to the bladder, prostate gland, and rectum. The term recto-vesical has also been restricted to the portion of the sheet which extends between the rectum and the bladder and encloses the seminal vesicles (Cunningham), and if the term is to be employed at all, this application of it seems to be the preferable one.

Confusion has also existed in the application of the term "white line," since it has been made to include both the arcus tendineus proper and the thickened band from which the levator ani takes its origin (*arcus tendineus m. levatoris ani*). These two bands are, however, quite distinct, especially anteriorly, as a careful inspection of the subject will demonstrate, and it seems preferable to restrict the term "white line" to that from which the levator ani arises, naming that at which the fascia endopelvina begins the arcus tendineus.

(*a*) THE PELVIC MUSCLES.

1. Levator ani. 2. Coccygeus.
3. Pyriformis.

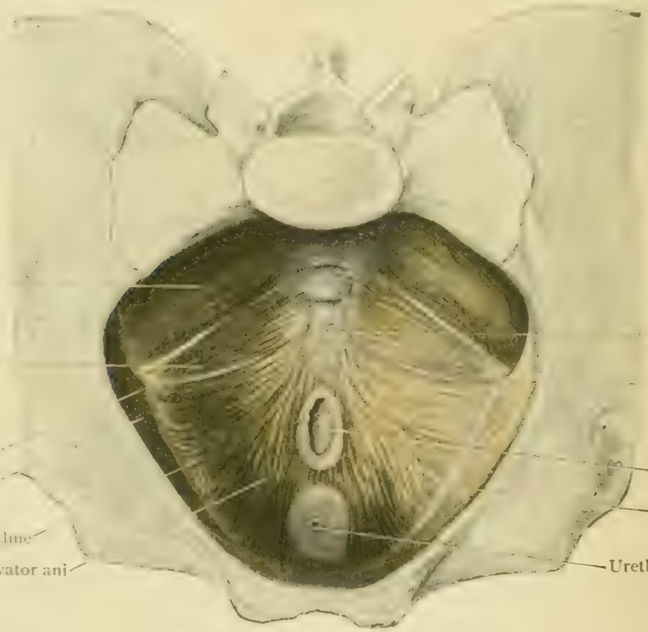
The floor of the pelvis is formed by two muscles which constitute an almost complete partition, the *pelvic diaphragm*, separating the pelvic from the perineal region. The more anterior and larger of these muscles is the levator ani, the coccy-

geus lying along its posterior margin. Above the upper margin of the latter, and forming the posterior wall of the pelvis, is the pyriformis. Slight intervals occupied by connective tissue usually exist between the coccygeus and the other two muscles, presenting opportunities for pelvic hernias.

1. Levator Ani (Fig. 551).

Attachments.—The levator ani *arises* from the posterior surface of the body of the os pubis in front, from the spine of the ischium behind, and in the interval between these two points from a thickening of the upper border of the obturator fascia, the white line. From this long line of origin the fibres converge downward and medially to be *inserted* into the sides and tip of the coccyx, into a tendinous raphe extending in the median line between the tip of the coccyx and the anus, and into the sides of the lower part of the rectum. The fibres from the most anterior portion of the origin pass almost directly backward and downward to reach the sides of the rectum, and between them and the corresponding fibres of the muscle of the opposite side is a

Fig. 551.



Muscular floor of pelvis, viewed from above.

space, occupied in the male by the lower part of the prostate gland and in the female by the base of the bladder and lower part of the vagina, the fascia endopelvina in this region coming into contact with the upper surface of the superior layer of the triangular ligament of the perineum.

Nerve-Supply.—The posterior portion of the muscle is supplied by a special branch from the third and fourth sacral nerves, the anterior portion by twigs from the inferior hemorrhoidal branches of the pudic nerve.

Action.—To bend the coccyx forward and to raise the pelvic floor and viscera.

Variations.—The levator ani is always a well-developed muscle, although the extent of its attachment to the sides of the coccyx varies inversely to the attachment of the coccygeus to that bone. There is usually to be found a dividing line extending across the muscle on a level with the junction of the superior ramus of the pubis with the ilium and separating those fibres which are inserted into the coccyx and the posterior portion of the fibrous raphe from those which pass to the anterior part of the raphe and the rectum. Each of the portions so separated is supplied by a separate nerve, and this, combined with the results of comparative anatomy, seems to show that the posterior portion of the levator is really a muscle quite distinct from the anterior portion. It has been termed the *m. ilio-coccygeus*. Furthermore, it seems probable that

the anterior portion is composed of two morphologically distinct muscles, one of which arises from the pubis and anterior part of the white line and is inserted into the median fibrous raphe, whence it is termed the *m. pubo-coccygeus;* while the other, situated beneath,—*i.e.*, superficial to the pubo-coccygeus,—consists of those fibres which arise from the pubis and are inserted into the rectum, and is termed the *m. pubo-rectalis.*

It may be added that in the lower mammals the muscles corresponding to the ilio-coccygeus and pubo-coccygeus are inserted into the caudal vertebræ and act as lateral flexors of the tail.

2. Coccygeus (Figs. 551, 603).

Attachments.—The coccygeus, which forms the posterior and lesser portion of the diaphragma pelvis, lies immediately behind the levator ani. It *arises* from the spine of the ischium and is *inserted* into the sides of the sacrum and coccyx.

Nerve-Supply.—From the third and fourth sacral nerves.

Action.—To assist the levator ani in raising the pelvic floor. It also flexes the coccyx laterally.

Variations.—Occasionally the insertion of the coccygeus is confined to the sides of the sacrum, in which cases its coccygeal area is occupied by fibres of the levator ani. The muscle is sometimes termed the *ischio-coccygeus*, and is represented in the lower mammals by a muscle attached to the caudal vertebræ and acting as a lateral flexor of the tail.

The Sacro-Coccygeus Anterior.—Occasionally muscular fibres are to be found arising from the ventral surface of the sacrum and inserting into the coccyx. They form what is termed the *sacro-coccygeus anterior* or *curvator coccygis*, and apparently belong to the hyposkeletal group of muscles.

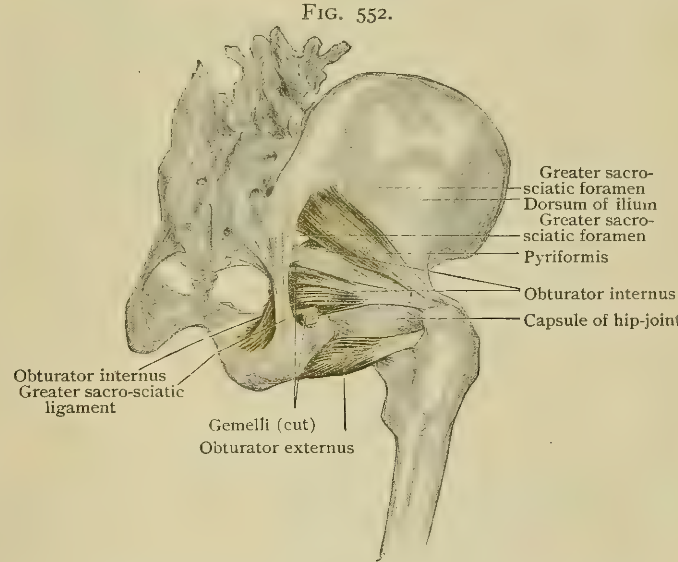
3. Pyriformis (Figs. 551, 552, 602.)

Attachments.—The pyriformis (m. piriformis) *arises* from the ventral surface of the sacrum, between the first, second, third, and fourth sacral foramina. It passes laterally through the great sciatic foramen, receiving a bundle of fibres from the upper margin of the foramen, and is *inserted* into the summit of the great trochanter, its tendon shortly before its insertion becoming closely united with that of the obturator internus.

Nerve-Supply.—By branches from the sacral plexus from the first and second sacral nerves.

Action.—To rotate the thigh outward and to draw it slightly outward and backward.

Fig. 552.



Deep dissection, showing insertion of pyriform, internal and external obturator muscles.

Relations.—By its anterior surface, while within the pelvis, the pyriformis is in relation to the sacral plexus, the anterior branches of the internal iliac vessels, and the rectum. It lies immediately above the upper border of the coccygeus muscle. Outside the pelvis it is usually separated from the capsule of the hip-joint by the gluteus minimus and is covered by the gluteus medius. Above the upper border of the muscle at its exit from the greater sciatic foramen are the gluteal vessels and the superior gluteal nerve, while below its lower border, between this and the superior gemellus, are the sciatic and internal pudic vessels and the pudic, sciatic, small sciatic, and inferior gluteal nerves. A bursa, the *bursa m. pyriformis*, intervenes between the tendon of the muscle and the summit of the great trochanter.

Variations.—The pyriformis is occasionally absent, and it may be more or less fused with the gluteus minimus or medius. Frequently it is divided into two or more portions by being perforated by the sciatic nerve.

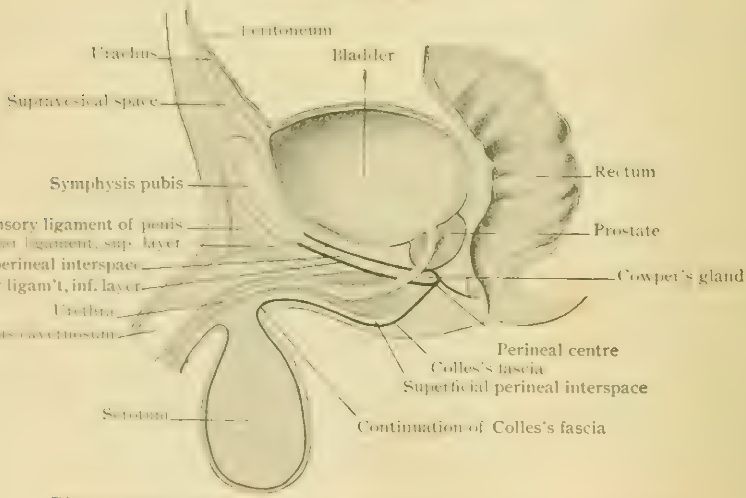
From the comparative stand point the pyriformis is to be regarded, in part at all events, as a portion of the musculature extending between the axial skeleton and the pelvic girdle or limb, and is represented in the lower vertebrates by the *caudo-femoralis*.

(b) THE PERINEAL MUSCLES.

1. Sphincter ani externus.
2. Transversus perinæi superficialis.
3. Ischio-cavernosus.
4. Bulbo-cavernosus.
5. Transversus perinæi profundus.
6. Compressor urethræ.

In the early stages of development, while the urogenital ducts and the digestive tract open into a common terminal cavity, the cloaca, muscle-fibres derived from the second, third, and fourth sacral myotomes arrange themselves in a flat layer around the external aperture of the cavity, forming what is termed the *sphincter cloacæ*. Later, with the division of the cloaca into a urogenital and a rectal portion and the resulting formation of the perineum, this primary sphincter becomes divided into two portions, one of which forms a sphincter ani, while the more anterior portion gives rise to the muscles of the perineum. The fibres of this latter portion undergo various modifications in accordance with the changes which

FIG. 553.



Diagrammatic sagittal section, showing relations of fascial layers of perineum.

take place in the urogenital sinus, and a horizontal separation of the original sphincter into two layers also occurs, whereby the perineal muscles are arranged in two layers separated by the superior fascia of the urogenital trigone.

The muscles formed during these changes retain the original sheet-like form of the sphincter cloacæ and are for the most part pale in color, resembling not a little in their general character the platysma muscles of the face. They show a considerable amount of difference in their development in different individuals, numerous accessory muscles having been described by various authors, some of which will be referred to in the succeeding descriptions.

The Superficial Perineal Fascia.—The superficial perineal fascia, being continuous anteriorly with the superficial fascia of the lower portion of the anterior abdominal wall, is, like this, composed of two layers. The more superficial layer usually contains a certain amount of fat, and, as in the abdomen, is really the panniculus adiposus of the skin. The deeper layer, which has been termed the *fascia of Colles*, forms a continuous membrane which is attached at the sides to the rami of the pubes and ischia and in front becomes continuous with the dartos of the

scrotum (or fascia of the labia majora) and on either side of this with the corresponding layer of the abdomen. Behind it unites with the posterior border of the trigonum urogenitale on a line extending between the two ischial tuberosities, and thence is continued backward, forming a single sheet with the superficial layer, to unite with the superficial fascia of the gluteal region. This posterior portion of the superficial perineal fascia may conveniently be termed the *circumanal fascia.*

By the union of the deep layer of the superficial fascia with the triangular ligament behind, an almost completely enclosed space is formed between the two structures ; it is open only anteriorly where it communicates with the areolar spaces between the superficial and deep layers of the abdominal fasciæ. This space is the *superficial perineal interspace*, and contains the bulb and spongy portion of the urethra, the corpora cavernosa, and certain of the perineal muscles.

The Trigonum Urogenitale.—The trigonum urogenitale, more usually called the *triangular ligament* of the perineum, is formed by the deep fascia of the perineum, and, like the superficial fascia, is composed of two layers, the *superior* and *inferior* (fasciae trigoni urogenitalis superior et inferior). At the sides both layers are attached to the rami of the pubes and ischia, in front to either edge of the lower border of the pubis, and behind they unite with each other and with the deep layer of the superficial fascia along a line extending transversely across the perineum between the tuberosities of the ischia. Between the two layers there is a completely closed space, the *deep perineal interspace*, in which are to be found the membranous portion of the urethra, the bulbo-urethral glands, the pudic vessels and nerves, and, in front, the subpubic or arcuate ligament of the pubis.

At their lateral insertions the layers of the trigone are continuous with the obturator fascia, and the superior layer is fused above with the portion of the fascia endopelvina which invests the lower surface of the prostate gland (or the base of the bladder). The trigone is perforated by the urethra and, in the female, by the vagina, and anteriorly the dorsal vein of the penis passes through it immediately behind the subpubic ligament of the pubis, the fibres of the trigone immediately behind the opening for the vein being thickened to form a transverse band known as the *transverse ligament of the pelvis.*

1. Sphincter Ani Externus (Fig. 554).

Attachments.—The external sphincter of the anus consists of a group of fibres which surround the terminal portion of the rectum, the superficial fibres standing in close relationship with the integument. Its fibres *arise* posteriorly from the coccyx and from the raphe extending from that bone to the anus, and, passing forward around the anus, are *inserted* into the superficial fascia and the central tendon of the perineum, and may in some cases be continued forward to join with the fibres of the superficial transverse perineal and bulbo-cavernosus muscles.

The *central tendon* of the perineum is situated in the median line about 2.5 cm. in front of the anus, and is the point of union of five muscles,—namely, the external sphincter ani, the two superficial transversi perinei, and the bulbo-cavernosi.

Nerve-Supply.—From the fourth sacral nerve and the inferior hemorrhoidal branches of the pudic.

Action.—To close the anal aperture. It also serves to fix the central tendon of the perineum during the contraction of the bulbo-cavernosi.

Variations.—The common embryological origin of the external sphincter ani and the perineal muscles is indicated by the extension forward of the fibres of the former to join the bulbo-cavernosus, and occasionally a fasciculus of it extends as far forward as the base of the scrotum, forming what has been termed the *retractor scroti.*

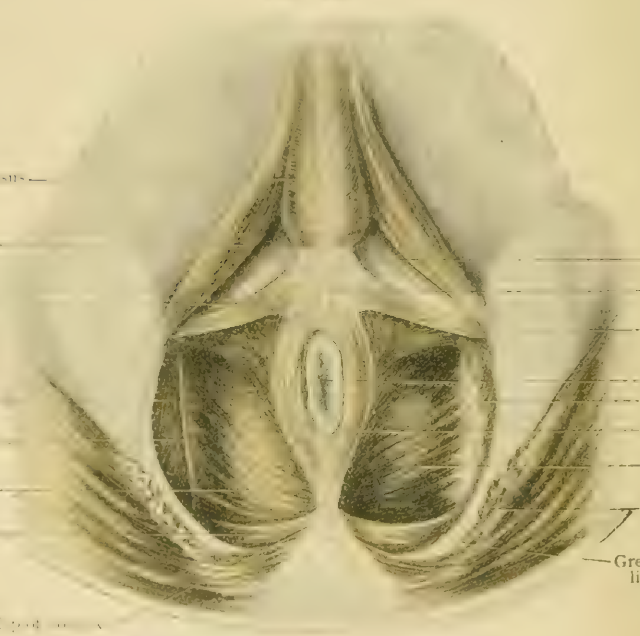
The longitudinal muscle-fibres of the lower portion of the rectum pass below into a sheet of connective tissue, which divides into three more or less distinct layers extending to the integument. The outer two of these layers traverse the substance of the external sphincter ani, a portion of the outermost one being continued backward to the region of the coccyx on each side of the median line as a moderately strong band known as the *ano-coccygeal ligament.* By these layers of fibrous tissue the external sphincter is divided, sometimes quite distinctly, into three portions which have been regarded as distinct muscles. One of these lies immediately beneath the skin surrounding the anus, and has consequently been termed the *sphincter*

subcutaneus. The *sphincter superficialis* is that portion of the muscle which lies above and to the outer side of the sphincter subcutaneus, while more deeply still, and forming a ring-like mass of fibres closely encircling the rectal wall, is the *sphincter profundus*. It is from the sphincter subcutaneus that the retractor scroti, when present, is derived, and fibres from the sphincter superficialis are frequently prolonged in front of the anus to various insertions, as, for instance, to the tuber ischii, the lower layer of the trigonum urogenitale, or even the sheath of the corpora cavernosa. This layering of the external sphincter is probably a relic of the separation of the sphincter cloacæ into two layers, the subcutaneous and superficial sphincters representing a portion of the superficial layer, while the deeper one is responsible for the sphincter profundus.

2. Transversus Perinei Superficialis (Fig. 554).

Attachments.—The superficial transverse perineal muscle is an exceedingly variable sheet of muscle-fibres situated in the posterior portion of the superficial perineal interspace. In its typical form it may be described as a band of fibres which

Fig. 554.



Muscles of male perineum and pelvic floor, seen from below.

arises from the medial surface of the ischial tuberosity and passes directly medially to be *inserted* into the central tendon of the perineum.

Nerve-Supply.—From the perineal branches of the pudic nerve.

Action.—To assist in fixing the central tendon of the perineum during the contraction of the bulbo-cavernosi.

Variations.—The muscle may occasionally be entirely absent. It frequently receives fibres from the anterior (pubo-rectal) portion of the levator ani and from the external sphincter ani and makes connections with the bulbo-cavernosi.

3. Ischio-Cavernosus (Fig. 554).

Attachments.—The ischio-cavernosus, also named the *erector penis* (*erector clitoridis*), represents the lateral portion of the sphincter cloacæ. The two muscles occupy the lateral parts of the superficial perineal interspace, each *arising* from the base of the tuberosity of the ischium, enclosing the base of the crus penis (clitoridis) as in a sheath, and passing forward to be *inserted* into the corpus cavernosum. The muscle in the female differs from that of the male only in size.

Nerve-Supply.—From the perineal branches of the pudic nerve

Action.—To compress the corpus cavernosum and thus assist in producing or maintaining erection of the penis (or clitoris).

4. Bulbo-Cavernosus (Fig. 554).

Attachments.—The bulbo-cavernosus differs somewhat in its relations in the two sexes. In the male, in which it is also termed the *accelerator urinæ*, the two muscles of opposite sides are united in a median fibrous raphe which extends forward from the central tendon of the perineum over the bulb and corpus spongiosum. *Arising* from this raphe, the fibres are directed laterally and forward over the bulb and corpus spongiosum and are *inserted* into the under surface of the inferior layer of the urogenital trigone and into the fibrous sheath of the corpus cavernosum, some of the more anterior fibres being continued dorsally to insert into the fascia covering the dorsum of the penis and forming what has been termed the *muscle of Houston*, or *compressor venæ dorsalis penis.*

In the female, in which the muscle has been termed the *sphincter vaginæ* (Fig. 1732), the two muscles of opposite sides are widely separated from each other by the vagina, which they surround. They *arise* from the central tendon of the perineum, pass forward, investing the bulbi vestibuli, and are lost in the fascia covering the corpora cavernosa and the dorsal surface of the clitoris.

Nerve-Supply.—From the perineal branches of the pudic nerve.

Action.—To compress the bulb and corpus spongiosum and so tend to expel any fluid contained in the urethra. The fibres which pass to the dorsum of the penis (or clitoris) may aid slightly in the erection of that organ, either directly or by compressing the dorsal vein.

Variations.—The posterior portion of the muscle, that surrounding the bulb, is unrepresented in the female and is frequently distinctly separable from the anterior part in the male; it has been termed the *compressor bulbi*. The deeper fibres of this part of the muscle are separated from the more superficial ones by a thin layer of areolar tissue, and have been regarded as forming a distinct muscle, the *compressor hemisphericum bulbi*, which closely surrounds the bulb, the two muscles of either side interlacing above the bulb so as to form practically a single muscle very variable in its development. Finally, fibres may arise from the ischial tuberosities in common with those of the transversi superficiales and pass forward and medially to unite with the bulbo-cavernosi forming what have been termed the *ischio-bulbosi.*

5. Transversus Perinæi Profundus (Fig. 1629).

Attachments.—The deep transverse perineal muscle is situated in the posterior part of the deep perineal interspace. It *arises* from the medial surface of the inferior ramus of the ischium and passes transversely inward to the median line, where it partly unites with its fellow of the opposite side and partly *inserts* into the central tendon of the perineum.

Nerve-Supply.—From the perineal branches of the pudic nerve.

Action.—To assist in fixing the central tendon of the perineum.

6. Compressor Urethræ (Fig. 1629).

Attachments.—The compressor or constrictor of the urethra (**m. sphincter urethrae membranaceae**) in the male is a thin sheet of muscle-tissue situated in the deep perineal interspace anterior to the deep transversus perinæi. It *arises* from the inner surface of the inferior ramus of the pubis and is *inserted* by passing medially to surround the membranous portion of the urethra, its anterior fibres forming a median raphe with those of the opposite side. The posterior fibres of the muscle enclose the bulbo-urethral gland.

In the female the fibres are *inserted* into the walls of the vagina as it traverses the deep perineal interspace.

Nerve-Supply.—From the perineal branches of the pudic nerve.

Action.—To constrict the membranous urethra and, in the female, also to flatten the wall of the vagina.

The *m. ischio-pubicus* is a small muscle situated at the side of the deep perineal interspace. It arises from the inferior rami of the ischium and pubis and passes anteriorly to be attached to the arcuate ligament of the pubis. It is frequently wanting.

THE APPENDICULAR MUSCLES.

The limbs make their appearance as two pairs of flat buds (Fig. 69), the upper pair being situated in the lower cervical and the lower pair in the lower lumbar and upper sacral regions. Into the buds processes extend from the myotomes of the regions concerned and apparently give rise to the more proximal muscles of the limb, but that they are the source of all the limb musculature is as yet undetermined. The greater mass of this musculature develops from a blastema which occupies the interior of the limb-bud and which cannot at first be distinguished from that which gives rise to the limb skeleton, and whether it represents a condensation of tissue whose fundamental derivation is the myotomes or is a derivative of the ventral mesoderm has not yet been definitely decided.

However that may be, the limb musculature stands in relation to the anterior divisions of definite spinal nerves, that of the upper limb being supplied by the lower five cervical and the first thoracic nerves and that of the lower limb by the lower four lumbar and upper three sacral nerves, and, furthermore, there is a distribution of these nerves to the muscles which may well be regarded as segmental. It is also worthy of note that in those regions of the trunk in which the limbs develop the ventral musculature is either very much reduced or, as in the lower limb, practically wanting.

An examination of the limb muscles shows that they may be regarded as being arranged in a ventral or pre-axial group and a dorsal or post-axial group, and in harmony with this arrangement the nerve-fibres which pass to the muscles arrange themselves in ventral or pre-axial and dorsal or post-axial groups. In the fore-limb the dorsal group is represented by the posterior fasciculus or cord of the brachial plexus, while the ventral one is distributed between the lateral and medial fasciculi. In the lower limb the correct relationships of the two groups of muscles and their nerves are less readily perceivable, owing to the forward rotation which the limb has undergone in order to bring its axis into a plane parallel with that of the sagittal plane of the body, a rotation which brings it about that in the adult, except in the more proximal portion of the limb, the pre-axial musculature is on the posterior and the post-axial on the anterior surface. The pre-axial nerve-fibres are distributed mainly by the obturator and greater sciatic (internal popliteal) nerves, while the post-axial ones pass to their destinations by way of the anterior crural and greater sciatic (external popliteal); and in this connection it is interesting to note that the fibres of the external popliteal or peroneal, if traced to their exit from the spinal foramina, will be found to lie dorsal to those of the internal popliteal or tibial, notwithstanding that the former are supplied to the anterior and the latter to the posterior muscles of the leg.

In this arrangement into pre-axial and post-axial groups there is, accordingly, to be found a clue to the proper understanding of the relations of the nerves to the muscles of the limbs, and a further examination of the two groups will reveal indications of a segmental distribution of the nerves and muscles in each. This arrangement may be most satisfactorily understood by means of a diagram (Fig. 555) showing the arrangement of the muscles and nerves in what may be regarded as its fundamental condition. The limb-bud may be regarded as a flat plate whose surfaces are directed dorsally and ventrally. Into the upper portion of this plate the uppermost of the spinal nerves which are associated with it is prolonged, its post-axial and pre-axial fibres passing respectively to either side of its frontal plane, and the succeeding nerves are similarly prolonged into it in succession from above downward. The nerves, however, which lie along the upper and in the lower limb also along the lower borders of the bud are not prolonged into it quite so far as the others, the free edge of the plate being, as it were, rounded off, so that it is only the more central (or upper) nerves of the series that reach that portion of the bud from which the foot (or hand) and digits will be developed.

It follows from this arrangement that in the adult each spinal nerve concerned supplies a portion of both the pre-axial and post-axial groups of muscles, and,

furthermore, that the muscle-fibres in succession from one border of the limb to the other are supplied by successive nerves, those supplied by the uppermost and, in the pelvic limb at least, the lowermost nerves extending only to the neighborhood of the knee (or elbow) or even a shorter distance into the limb. Thus, in the fore-limb one may expect to find the more lateral muscles of the shoulder and arm supplied by fibres from the uppermost nerves of the brachial plexus, those lying towards the middle of the shoulder and brachial regions and in the lateral portion of the antibrachium and hand regions by the middle nerves, and those along the medial portion of the limb by the lower ones. In the lower limb, however, owing to the rotation which it has undergone, the arrangement is to a certain extent reversed, and although in the more proximal muscles the fibres are supplied by successive nerves from above downward, lower down the fibres from the upper nerves are to be found along the inner side of the leg and those from the lower nerves along the outer side.

Fig. 555.

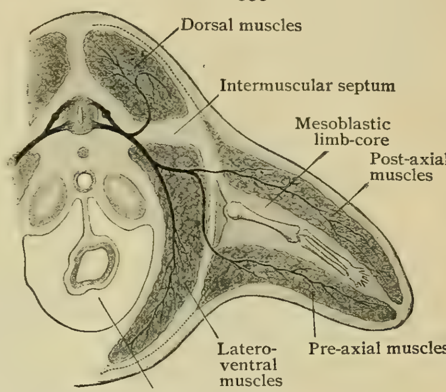


Diagram of pre- and post-axial groups of limb-muscles. (*Kollmann.*)

If, then, an originally segmental arrangement of the muscle-fibres of the limbs is to be recognized, the segments must run parallel to the long axis of the limb, and this arrangement has permitted their free consolidation to form the various muscles found in the adult, very few indeed of which are supplied by a single nerve, and represent, accordingly, portions of a single primitive segment. Furthermore, the adaptation of the muscles to act effectively on the various joints of the limbs has brought about a transverse division of the segments, and has also led to a complete degeneration of the portions of some of the segments in one part of the limb while they are retained in another. Thus, for example, in the pre-axial musculature of the brachial region no trace is to be found of the segments supplied by the eighth cervical and first dorsal nerves, although the eighth cervical is represented in the post-axial musculature and both in the pre-axial musculature of the forearm.

On account of the occurrence of both fusion and degeneration, little trace of an original segmental arrangement of the muscle-fibres is to be found in the adult limb muscles, and their classification according to the segments from which they may be derived is not feasible. Comparative anatomy, however, shows that primarily the limb muscles were arranged with relation to the various joints of the limb, each muscle, as a rule, passing over but a single joint, and in this relation may be found a basis for classification. In man the original relations have been modified in many cases by an alteration in one of the original points of attachment of a muscle so that it passes over two joints, or by the end-to-end union of originally distinct muscles so that the same result is brought about. Making allowance for these modifications, however, the muscles of the upper limb may be classified into (1) those passing from the axial skeleton to the pectoral girdle, (2) those passing from the girdle to the brachium or arm, (3) those passing from the brachium to the antibrachium or fore-arm, (4) those passing from the antibrachium to the carpus, and (5) the digital muscles. Similarly in the lower limb, in which, however, owing to the firm articulation of the pelvis to the sacrum, the first group of muscles is practically unrepresented, or at least may be placed with those of the second group extending from the pelvic girdle to the femur. With this grouping there may be combined a recognition of the pre-axial and post-axial musculature, these terms being used in the lower limb as well as in the upper to indicate the relationships which obtained before the rotation of the limb.

THE MUSCLES OF THE UPPER LIMB.

THE MUSCLES EXTENDING BETWEEN THE AXIAL SKELETON AND THE PECTORAL GIRDLE.

(a) THE PRE-AXIAL MUSCLES.

1. Pectoralis major. 2. Pectoralis minor.
3. Subclavius.

The Pectoral Fascia.—The *superficial* pectoral fascia is continuous above with the superficial cervical and below with the superficial abdominal fasciæ, and covers the entire anterior wall of the thorax. It usually contains a considerable amount of fat and has embedded in it the mammary gland.

The *deep* fascia is attached above to the clavicle, and forms a thin membrane closely adherent to the surface of the pectoralis major, at the lower border of which

FIG. 556.

Dissection of thoracic wall after removal of greater part of pectoralis major, showing clavi-pectoral fascia enclosing pectoralis minor and continuous with axillary fascia.

it becomes continuous with the axillary fascia. Medially it is attached to the ventral surface of the sternum and laterally it is continuous with the fascia covering the deltoid.

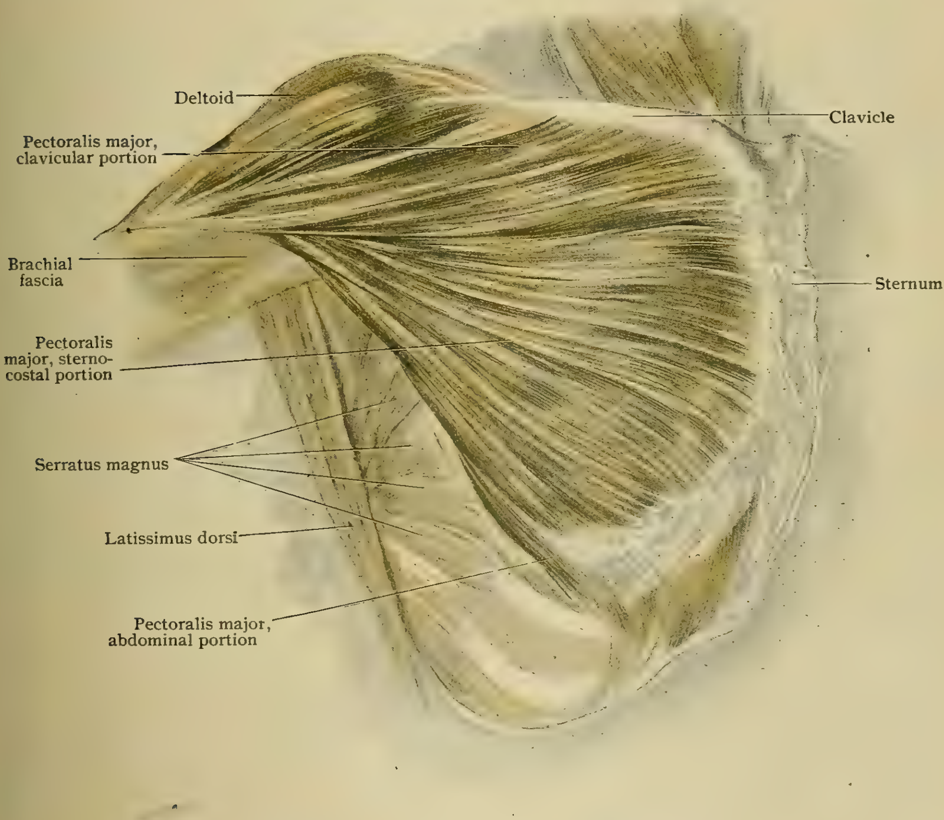
Beneath the deep fascia there arises from the clavicle a second sheet of fascia (*clavi-pectoral fascia*) (Fig. 556) which encloses the subclavius muscle and is then continued downward to the upper border of the pectoralis minor. There it divides into two sheets which enclose the muscle and at its lower margin unite to form a single sheet which becomes continuous with the axillary fascia close to the lower border of the pectoralis major. The portion of this fascia which intervenes between the clavicle and the subclavius muscle and the upper border of the pectoralis minor is termed the *coraco-clavicular fascia* or *costo-coracoid membrane*. It is prolonged laterally along the upper border of the pectoralis minor, over the upper portion of the axillary vessels, to the coracoid process, its outer portion being thickened to form

a band, the *costo-coracoid ligament* (Fig. 560), which passes obliquely downward and laterally from the clavicle to the coracoid process. The coraco-clavicular fascia occasionally contains muscle-fibres (the *m. coraco-clavicularis*), and is usually perforated by the cephalic vein on its way to join the axillary, by the thoraco-acromial artery, and by the external anterior thoracic nerve.

1. Pectoralis Major (Fig. 557).

Attachments.—The pectoralis major is a strong fan-shaped muscle situated on the anterior thoracic wall. It is composed of three portions: (1) the *pars clavicularis*, which *arises* from the inner half of the anterior border of the clavicle; (2) the *pars sterno-costalis*, which *arises* from the anterior surface of the sternum and the upper six costal cartilages; and (3) the *portio abdominalis*, which *arises* from

Fig. 557.



Dissection of thoracic wall, showing pectoralis major.

the upper part of the anterior layer of the sheath of the rectus abdominis. From these origins the fibres are directed laterally to be *inserted* into the external bicipital ridge which extends downward from the greater tuberosity of the humerus, the lower fibres of the sterno-costal and the abdominal portions of the muscle passing behind those of the clavicular and upper portions, so that the tendon of insertion is U-shaped in section, consisting of two layers separated above but continuous below. A bursa is usually interposed between the posterior surface of the tendon and the anterior surface of the long head of the biceps humeri.

Nerve-Supply.—From the external and internal anterior thoracic nerves by fibres from the lower four cervical and the first thoracic nerves.

Action.—When the arm is abducted to a position at right angles to the body, the pectoralis major will draw the arm forward and at the same time will adduct it. As the arm approaches the vertical position, the adductor action becomes more pronounced and the flexor action less so, and a slight amount of internal rotation appears. When the arm is raised above the level of the shoulder and fixed, the muscle will assist in drawing the trunk upward, as in climbing, and it will also assist in raising the ribs in forced inspiration.

Variations.—In the lower mammals the pectoralis major is represented by a number of distinctly separate portions, a condition which may be indicated in man by a more than usual distinctness of the three portions of the muscle and by the occurrence of accessory slips. The sterno-costal and abdominal portions may be greatly reduced or even absent.

The *m. sternalis* is present in something over 4 per cent. of all cases examined. It is very variable in its development, and consists of fibres which arise anywhere from the third to the seventh costal cartilage, or even from the sheath of the rectus, and extends upward to be attached to the anterior surface of the sternum, the clavicle, or the tendon of the sterno-cleido-mastoid. Usually the fibres are directed vertically, but sometimes they may have a more or less oblique course.

The muscle has been variously regarded as a portion of the platysma, a downward prolongation of the sterno-cleido-mastoid, an upward prolongation of the rectus abdominis, and as a displaced portion of the pectoralis major. The fact that in the majority of cases it is supplied by branches from the anterior thoracic nerves indicates clearly its usual derivation from the pectoralis, but it is asserted that in certain cases it received its nerve-supply from the third and fourth intercostal nerves, in which cases it is more probably to be regarded as representing a thoracic portion of the rectus trunk muscles.

The *chondro-epitrochlearis* is a slip derived from the pectoralis major which takes its origin from the lower costal cartilages or the abdominal portion of the pectoralis and is inserted into the brachial fascia or the medial epicondyle of the humerus.

2. Pectoralis Minor (Fig. 560).

Attachments.—The pectoralis minor lies beneath the pectoralis major. It *arises* from the outer surface of the third, fourth, and fifth ribs and from the fascia covering the intervening intercostal muscles, and passes obliquely upward and laterally to be *inserted* into the coracoid process of the scapula.

Nerve-Supply.—By branches of the external and internal anterior thoracic nerves from the seventh and eighth cervical and first thoracic nerves.

Action.—To draw the lateral angle of the scapula downward and forward; if the scapula be fixed, to raise the ribs to which it is attached.

Relations.—The pectoralis minor is completely covered by the pectoralis major. It covers the outer surface of the upper ribs and their intercostal spaces, and near its insertion it passes over the middle portion of the axillary vessels and the cords of the brachial plexus.

3. Subclavius (Fig. 560).

Attachments.—The subclavius is an almost cylindrical muscle attached at one extremity to the anterior surface of the first costal cartilage and at the other to the under surface of about the middle third of the clavicle.

Nerve-Supply.—By a special nerve from the brachial plexus from the fifth and sixth cervical nerves.

Action.—To draw the outer end of the clavicle downward and forward.

Variations.—The subclavius seems to be the persistent representative of a group of muscles more perfectly developed in the lower mammals and especially in those in which the clavicle is more or less rudimentary. Muscle-bands, which represent portions of the group normally degenerated, are occasionally found in man, and on account of their variable relations have been described under various names. They may all be grouped, however, under three terms, the *sterno-chondro-scapularis*, the *scapulo-clavicularis*, and the *sterno-clavicularis* (Le Double). In the mammals which lack a clavicle—in many Ungulates, for example—a strong muscle-band passes transversely across the upper part of the thorax from the sternum and first costal cartilage to the scapula. This is the sterno-chondro-scapularis, and it occasionally occurs in man as a band arising from the points named, or from either one of them, or from the first rib, and inserting into the coracoid process of the scapula.

In those mammals which possess a rudimentary clavicle, such as the Rodents, only the terminations of the sterno-chondro-scapular persist, each inserting into the clavicle, and forming

the scapulo-clavicularis and the sterno-clavicularis. Each of these may occur as an anomaly in man, the sterno-clavicularis appearing under various forms, and passing either above, behind, or in front of the clavicle. It should be stated, however, that there is a possibility that some of the varieties of the sterno-clavicularis may really represent persisting portions of the muscular sheet which has given rise to the middle layer of the cervical fascia and to the sterno-hyoid and the omo-hyoid (page 545).

In the lower mammals a thin muscular sheet invests a greater or less portion of the trunk in intimate association with the integument, resembling in this respect the platysma. It is termed the *panniculus carnosus*, and in man is normally unrepresented. Occasional traces of it are found, however, and of these the most frequent is the muscle of the *axillary arch*, a somewhat variable band of muscle-tissue which passes across the anterior portion of the axillary cavity from the lateral border of the latissimus dorsi to the tendon of the pectoralis major. It presents considerable variation in its insertion, being connected sometimes with the biceps, the coraco-brachialis, the pectoralis minor, or the chondro-epitrochlearis, or being united with slips from the abdominal portion of the pectoralis major, or being inserted into the coracoid process of the scapula. It is supplied by branches from the anterior thoracic nerves.

(*b*) THE POST-AXIAL MUSCLES.

1. Serratus magnus.
2. Levator anguli scapulæ.
3. Rhomboideus minor.
4. Rhomboideus major.
5. Latissimus dorsi.

1. Serratus Magnus (Fig. 558).

Attachments.—The serratus magnus (**m. serratus anterior**) forms a large muscular sheet covering the lateral wall of the thorax. It *arises* by nine or ten fleshy digitations from the outer surfaces of the eight or nine upper ribs, the second rib giving attachment to two slips. Its fibres may be regarded as arranged in three groups : the uppermost group consists of fibres from the first and second ribs and is *inserted* into the ventral surface of the medial angle of the scapula ; the middle group, from the second and third ribs, is inserted into the ventral surface of the vertebral border of the scapula ; while the remaining fibres, constituting the strongest portion of the muscle, converge to the inferior angle of the same bone.

Nerve-Supply.—By the long thoracic nerve from the fifth, sixth, and seventh cervical nerves.

Action.—It serves to keep the scapula closely applied against the thoracic wall and draws it laterally. Since the portion inserted into the inferior angle is the strongest, a rotation of the scapula is produced whereby its lateral angle is raised. By this action the serratus plays an important part in the elevation (abduction) of the arm, since, in the first place, by fixing the scapula it allows the deltoid to expend all its action on the humerus instead of wasting part of it in tilting the acromion downward, and, in the second place, after the deltoid has completed its action and has raised the arm through about 90°, the further elevation through another right angle is accomplished by a rotation of the scapula resulting from the action of the serratus magnus and trapezius.

Variations.—Absence of a portion or the whole of the muscle has been observed. Its origin may extend as low as the tenth rib, and it may receive slips from the transverse processes of the cervical vertebræ and from the levator scapulæ.

2. Levator Anguli Scapulæ (Fig. 559).

Attachments.—This (**m. levator scapulae**) is an elongated muscle on the lateral surface of the neck. It *arises* from the transverse processes of the upper four cervical vertebræ and passes downward, forward, and laterally to be *inserted* into the medial angle and outer surface of the vertebral border of the scapula as far down as the base of the spine.

Nerve-Supply.—By the dorsal scapular nerve from the fifth cervical nerve.

Action.—To draw upward the medial angle of the scapula, producing a rotation of the bone contrary to that effected by the serratus anterior. If the scapula be fixed, the action is to bend the cervical portion of the spinal column laterally, rotating it slightly to the opposite side.

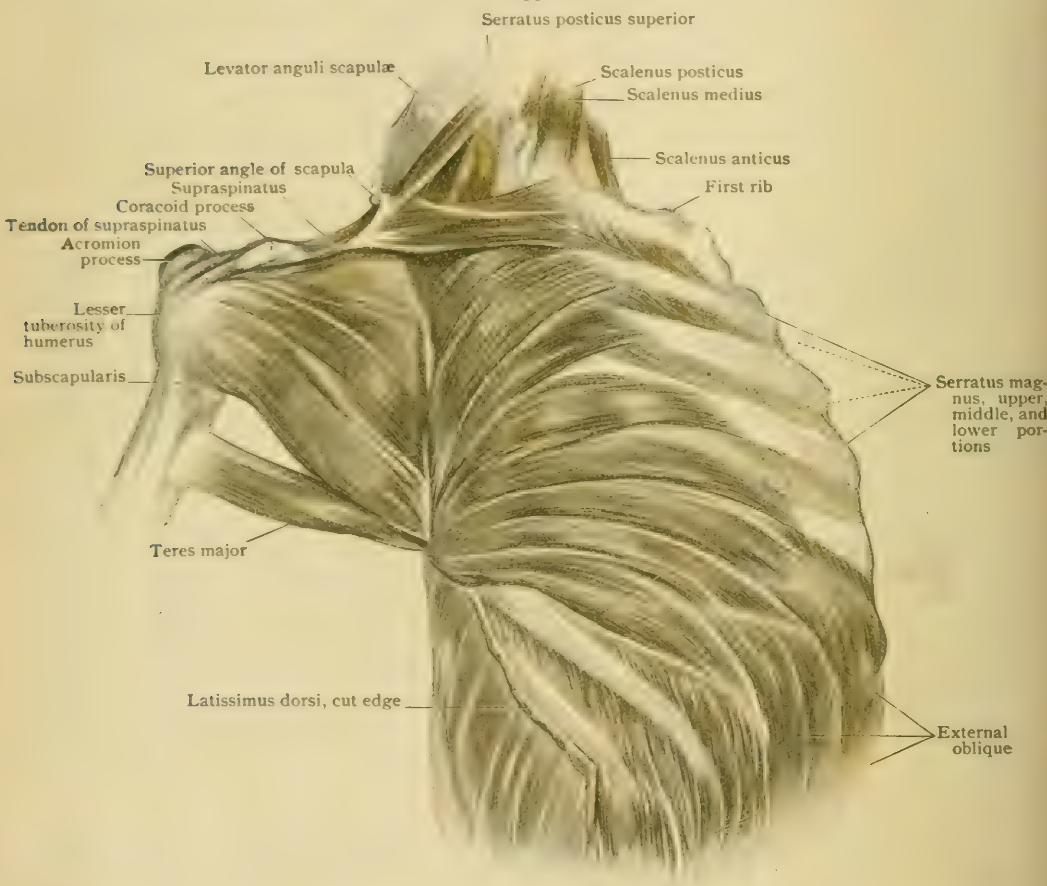
Variations.—The origin may extend to the transverse processes of all the cervical vertebræ, and may be continued upon the mastoid process above and upon the upper ribs below. Slips may occur connecting the levator with various neighboring muscles, the most interesting of these connections being that with the serratus magnus, since comparative anatomy shows that the levator was primarily continuous with that muscle.

A separated portion of the outer part of the muscle is occasionally inserted into the outer end of the clavicle, forming what is termed the *levator claviculæ*.

3. Rhomboideus Minor (Fig. 559).

Attachments.—The rhomboideus minor is a band-like muscle which *arises* from the lower part of the ligamentum nuchæ and from the spinous process of the

Fig. 558.



Dissection of thoracic wall, showing serratus magnus; clavicle has been removed and scapula drawn outward.

last cervical vertebra and passes laterally and downward to be *inserted* into the vertebral border of the scapula at the base of the spine.

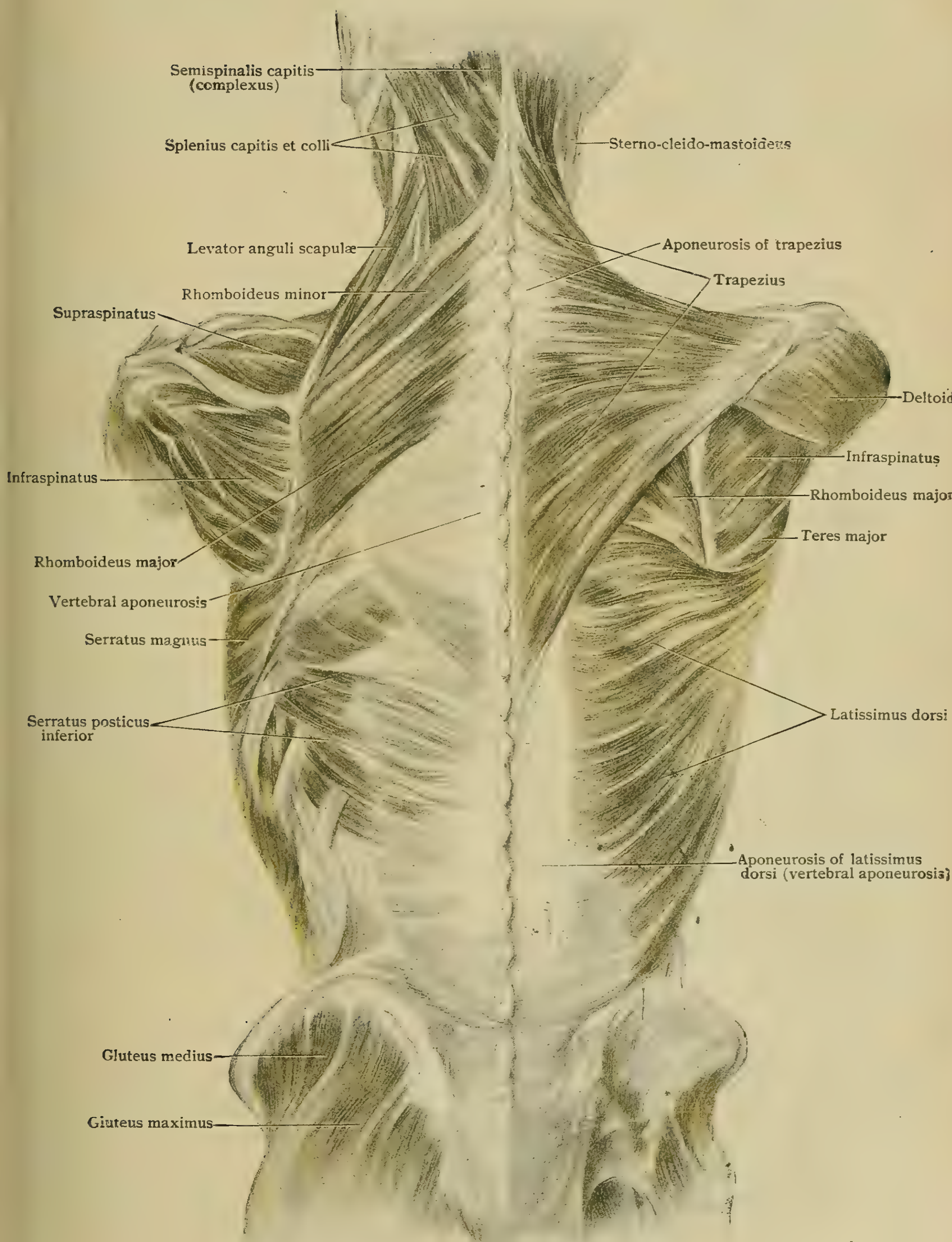
Nerve-Supply.—By the dorsal scapular nerve from the fifth cervical nerve.

Action.—To draw the scapula upward and medially, at the same time rotating it so that the lateral angle is moved downward.

4. Rhomboideus Major (Fig. 559).

Attachments.—The rhomboideus major immediately succeeds the rhomboideus minor, and is a quadrilateral sheet which *arises* from the spinous processes of the four upper thoracic vertebræ and from the intervening interspinous liga-

FIG. 559.



Superficial muscles of the back.

ments. It is directed downward and laterally and is *inserted* into the lower two-thirds of the vertebral border of the scapula.

Nerve-Supply.—By the dorsal scapular nerve from the fifth cervical nerve.

Action.—To draw the scapula upward and medially, at the same time rotating it so that the lateral angle is moved downward.

Variations of the Rhomboidei.—The rhomboidei are sometimes entirely wanting, and the origins of both muscles may be extended beyond the usual limits.

The *occipito-scapularis* is a muscle occasionally present which is intimately associated in its derivation with the rhomboids. It arises from the inner part of the superior nuchal line and passes downward between the trapezius and splenius to join the rhomboideus minor, inserting with it into the vertebral border of the scapula.

5. Latissimus Dorsi (Fig. 559).

Attachments.—The latissimus dorsi is a large triangular muscle which *arises* from the spinous processes of the last six thoracic vertebræ and the intervening interspinous ligaments beneath the origin of the trapezius, from the lumbo-dorsal fascia, from the posterior portion of the crest of the ilium, and by fleshy digitations from the outer surfaces of the lower three or four ribs. Its fibres pass upward and laterally over the inferior angle of the scapula, from which an additional slip is usually added to the muscle. It then curves around the lower border of the teres major and is *inserted*, ventrally to that muscle, into the crest of the inner tuberosity of the humerus. A mucous bursa (*bursa m. latissimi dorsi*) lies between the tendons of insertion of the latissimus dorsi and teres major.

Nerve-Supply.—By the long subscapular nerve from the seventh and eighth cervical nerves.

Action.—To draw the humerus downward, backward, and inward, at the same time rotating it inward, the action being that of the arm in swimming. If the humerus be fixed, as in climbing, it draws the pelvis and lower portion of the trunk upward and forward.

Variations.—The latissimus dorsi, like the serratus anterior and pectorales, is a muscle which has migrated extensively from the region of its first formation, the lower cervical region, and this migration can be witnessed in the ontogeny of the muscle. Consequently variations may be expected and do occur in the extent of the origin of the muscle, whose descent and backward migration to the vertebral column may be interrupted at various stages.

A great amount of variation of this nature is seen in its attachment to the crest of the ilium. In some cases this attachment extends so far forward as to meet the posterior extremity of the attachment of the external oblique of the abdomen, but usually this does not occur, and a triangular interval, known as the *triangle of Petit*, occurs between the borders of the two muscles and above the crest of the ilium. The floor of the triangle is formed by the internal obliquus abdominis, and, since the abdominal wall is here thinner than elsewhere, the triangle may occasionally be the seat of a lumbar hernia.

Closely allied to the latissimus dorsi is a muscle, the *m. dorso-epitrochlearis*, which occurs in 18 or 20 per cent. of cases. It takes its origin from the body or tendon of insertion of the latissimus and passes to the brachial fascia or to the medial epicondyle of the humerus. It has been regarded as an aberrant portion of the pectoralis group of muscles, but its supply by the musculo-spiral nerve places it among the post-axial muscles.

The Axillary Fascia.—The axillary fascia is a firm sheet which extends across from the lower border of the pectoralis major to that of the latissimus dorsi and teres major, forming the floor of the axilla. Laterally it passes over into the deep fascia of the arm, medially into the fascia covering the serratus magnus, and near the border of the pectoralis major it has inserted into it the downward continuation of the fascia which encloses the pectoralis minor (Fig. 556). It is pierced by numerous lymphatic vessels, and along its medial edge is considerably thickened to form a curved band, whose concavity is directed laterally, and which stretches across between the tendons of the pectoralis major and the latissimus, forming what is termed the *axillary arch*. Muscle-fibres are occasionally found in this arch (page 571).

The **axilla** is a pyramidal space intervening between the upper part of the brachium and the lateral wall of the thorax. Its apex is directed upward and the

base, which is formed by the axillary fascia, downward. Its ventral wall is formed by the pectoralis major and pectoralis minor, its dorsal wall by the latissimus dorsi, teres major, and subscapularis, and its medial wall by the serratus magnus. In the angle formed by the junction laterally of its ventral and dorsal walls lies the m. coraco-brachialis, and in the groove between that muscle and the posterior wall are the axillary vessels and the cords of the brachial plexus. The cavity of the axilla contains a considerable amount of fat and a variable number of lymphatic nodes ; it is traversed by the thoracic branches of the axillary vessels and by the intercosto-humeral nerve, and the long thoracic nerve passes downward along its medial wall to the serratus magnus.

THE MUSCLES PASSING FROM THE PECTORAL GIRDLE TO THE BRACHIUM.

Pre-Axial.	Post-Axial.	
1. Coraco-brachialis.	1. Supraspinatus.	4. Teres major.
	2. Infraspinatus.	5. Subscapularis.
	3. Teres minor.	6. Deltoideus.

(*a*) THE PRE-AXIAL MUSCLES.

1. Coraco-Brachialis (Figs. 560, 570).

Attachments.—The coraco-brachialis *arises* from the tip of the coracoid process of the scapula by a tendon common to it and the short head of the biceps. It extends downward along the humerus and is *inserted* at about the middle of its medial border.

Nerve-Supply.—By the musculo-cutaneous nerve from the seventh cervical nerve.

Action.—To draw the upper arm forward.

Relations.—It is crossed ventrally by the pectoralis major, and dorsally it is in relation with the tendons of the latissimus dorsi, the teres major, and the subscapularis, from the last of which its tendon is separated by a mucous bursa (*bursa m. coraco-brachialis*). Laterally the muscle is in contact with the short head of the biceps. It is usually pierced by the musculo-cutaneous nerve, and is in relation medially with the axillary artery and the median and ulnar nerves.

Variations.—Comparative anatomy shows that the coraco-brachialis is primarily an extensive muscle consisting of three portions, of which only the middle one and a part of the inferior are normally present in man. The variations which occur usually consist in the appearance of one or other of the missing portions. Thus the upper portion is sometimes represented by a *coraco-brachialis superior*, which arises from the coracoid process and passes laterally to be inserted into the lesser tuberosity of the humerus or into the capsule of the shoulder-joint, while the lower portion may be more completely represented by the insertion of the muscle extending as far down as the medial epicondyle of the humerus.

(*b*) THE POST-AXIAL MUSCLES.

1. Supraspinatus (Fig. 561).

Attachments.—The supraspinatus occupies the supraspinous fossa of the scapula, *arising* from the inner two-thirds of this and from the supraspinous fascia. Its fibres pass laterally and converge to a tendon which is *inserted* into the upper facet upon the greater tuberosity of the humerus and into the capsule of the shoulder-joint.

Nerve-Supply.—By the suprascapular nerve from the fifth and sixth cervical nerves.

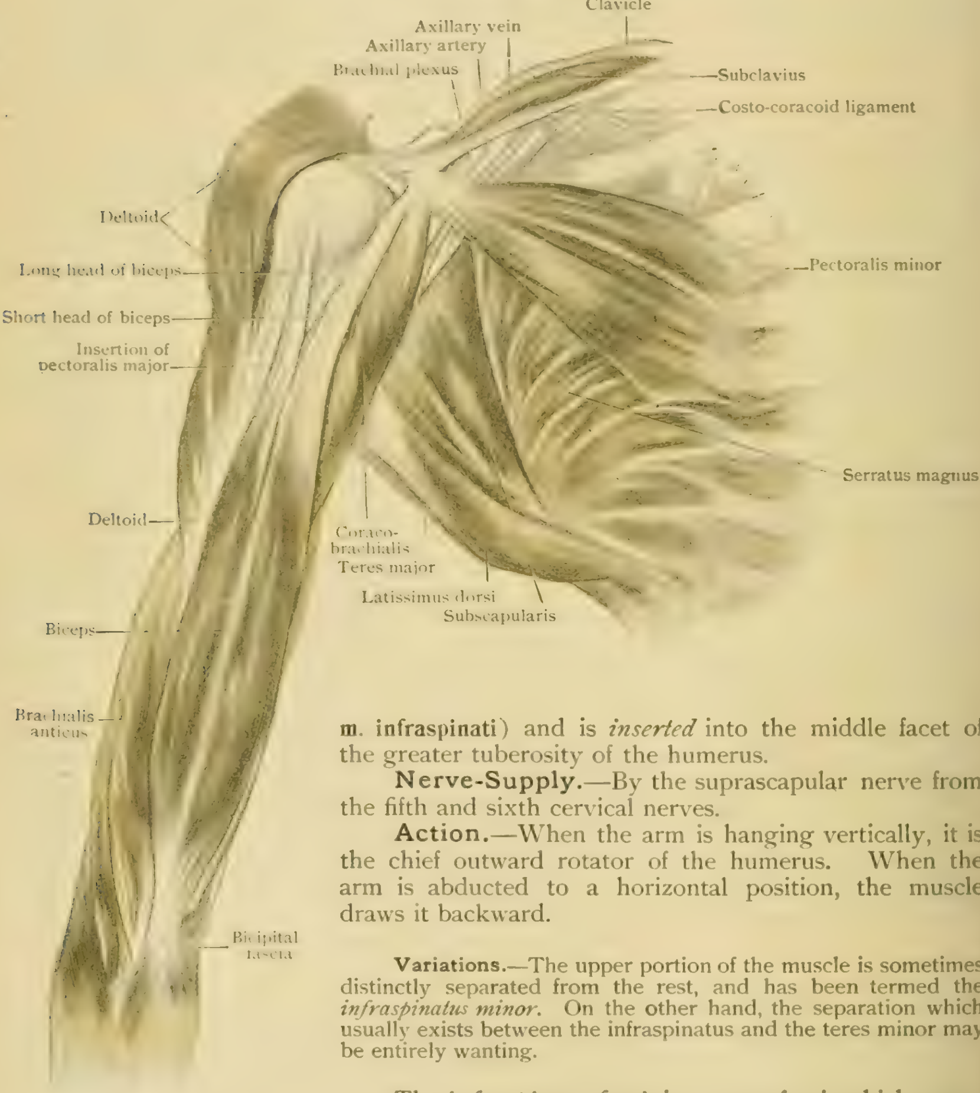
Action.—To abduct the arm.

The *supraspinous fascia* is the layer of connective tissue which covers the supraspinatus muscle. It is attached to the superior border of the scapula above, to the vertebral border medially, to the spine below, and gradually fades out laterally.

2. Infraspinatus (Figs. 561, 572).

Attachments.—The infraspinatus occupies the infraspinous fossa of the scapula and *arises* from the entire extent of the fossa, with the exception of a portion towards the axillary border of the bone. It also arises from the infraspinous fascia which covers it. The fibres pass laterally and converge to a strong tendon, which is frequently separated from the capsule of the shoulder-joint by a small bursa (**bursa m. infraspinati**) and is *inserted* into the middle facet of the greater tuberosity of the humerus.

Fig. 560.



Dissection of thoracic wall and anterior surface of arm.

Nerve-Supply.—By the suprascapular nerve from the fifth and sixth cervical nerves.

Action.—When the arm is hanging vertically, it is the chief outward rotator of the humerus. When the arm is abducted to a horizontal position, the muscle draws it backward.

Variations.—The upper portion of the muscle is sometimes distinctly separated from the rest, and has been termed the *infraspinatus minor*. On the other hand, the separation which usually exists between the infraspinatus and the teres minor may be entirely wanting.

The *infraspinous fascia* is a strong fascia which covers the infraspinatus and the teres minor, giving origin to some of the fibres of both muscles. It is attached above to the spine of the scapula, medially to its vertebral border, and fades out laterally into the brachial fascia.

3. Teres Minor (Fig. 561).

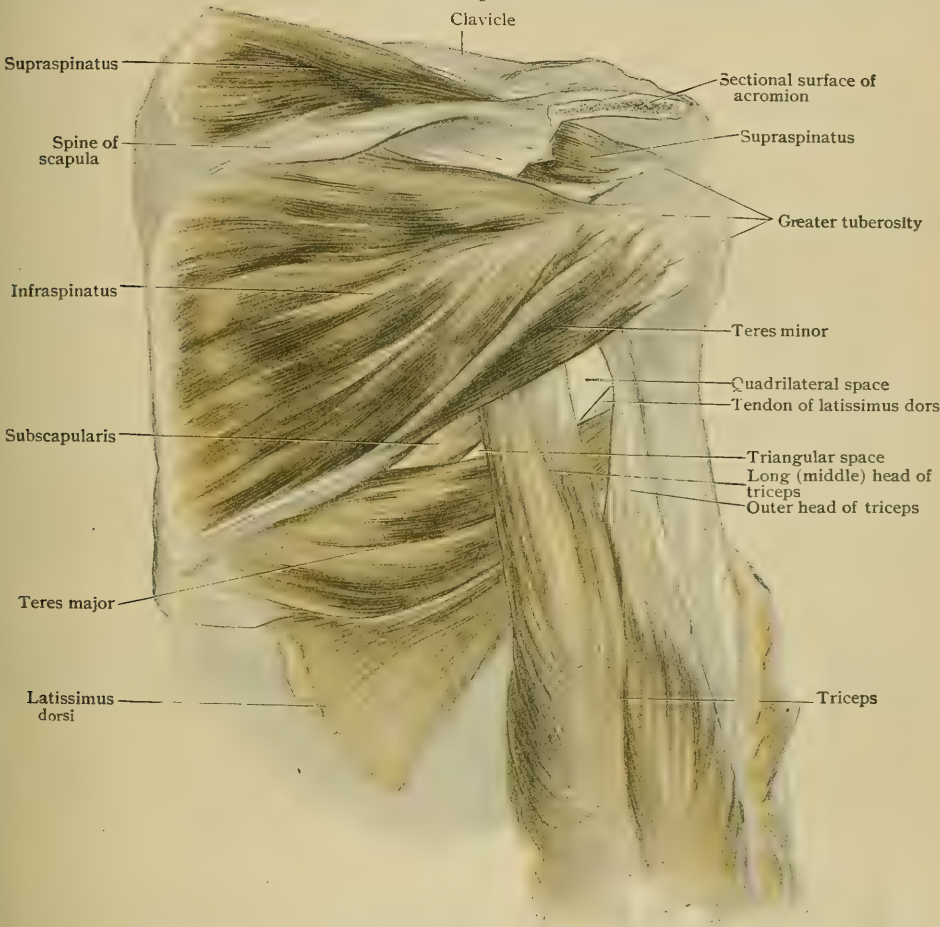
Attachments.—The teres minor *arises* from the upper two-thirds of the dorsal surface of the scapula, close to its axillary border, and from the infraspinous fascia.

It passes laterally along the lower border of the infraspinatus to be *inserted* into the capsule of the shoulder-joint and into the lower facet of the greater tuberosity of the humerus.

Nerve-Supply.—By the circumflex nerve from the fifth and sixth cervical nerves.

Action.—When the arm is vertical, it rotates the humerus outward; when it is horizontal, it draws it backward.

FIG. 561.



Posterior scapular muscles and part of triceps; outer part of acromion has been removed.

4. TERES MAJOR (Figs. 561, 572).

Attachments.—The teres major *arises* from the dorsal surface of the scapula, along the lower third of its axillary border, and passes laterally to be *inserted* into the crest of the lesser tuberosity of the humerus immediately dorsal to the insertion of the latissimus dorsi.

Nerve-Supply.—By the lower subscapular nerve from the fifth and sixth cervical nerves.

Action.—To draw the arm backward and medially, at the same time rotating it inward.

Relations.—The teres major is in relation below with the latissimus dorsi, which bends around its under surface so as to lie ventral to it at its insertion. Above it is in relation with the teres minor at its origin, but separates from it as it passes later-

ally, so that a triangular interval, the base of which is the humerus, lies between the two muscles. This interval is crossed by the long head of the triceps, which overlies the dorsal surface of the teres major, and is thus divided into a more medial *triangular space*, occupied by the dorsal scapular artery, and a more lateral *quadrangular space*, through which the posterior circumflex vessels and the circumflex nerve pass.

Variations.—Considerable variation occurs in the size of the teres major, an increase in the size of that muscle being associated with a diminution of that of the latissimus dorsi, and *vice versa*. The teres major is, indeed, to be regarded as fundamentally a portion of the latissimus.

5. Subscapularis (Fig. 558).

Attachments.—The subscapularis is a powerful muscle occupying the ventral (costal) surface of the scapula. It *arises* from nearly the whole of that surface, with the exception of a small portion near the neck of the bone, some fibres also taking origin from the subscapular fascia. The fibres pass laterally, converging to a strong tendon which is *inserted* into the lesser tuberosity of the humerus and to a certain extent into the capsule of the shoulder-joint.

Nerve-Supply.—By the upper and lower subscapular nerves from the fifth and sixth cervical nerves.

Action.—When the arm is vertical, the subscapularis acts as a powerful inward rotator of the humerus ; when the arm is abducted to a right angle with the body, the muscle serves to draw it forward.

Relations.—The subscapularis forms a considerable portion of the dorsal wall of the axilla, and is in relation, by its ventral surface, with the axillary vessels and the cords of the brachial plexus, and laterally with the coraco-brachialis and short head of the biceps. Its lower border is in contact with the teres major and with the dorsal scapular vessels and the circumflex nerve. Dorsally it is in contact with the long head of the triceps, and is separated from the neck of the scapula by the large *subscapular bursa* (**bursa m. subscapularis**) which frequently is continuous with the synovial cavity of the shoulder-joint.

Variations.—The subscapularis differentiates in the embryo from the same sheet which gives rise to the teres major and the latissimus dorsi. It is occasionally divided into two or more fasciculi, and sometimes there is separated from its lower portion a small muscle, termed the *subscapularis minor*, which arises from the axillary border of the scapula and is inserted into the crest of the lesser tubercle of the humerus and sometimes into the capsule of the shoulder-joint.

The *subscapular fascia* is a firm sheet of connective tissue which covers the ventral surface of the subscapularis. It is attached above, medially, and below to the border of the scapula and fades out laterally into the brachial fascia.

6. Deltoideus (Fig. 562).

Attachments.—The deltoid is a large triangular muscle which covers the shoulder as with a pad. It *arises* from the ventral border of the outer third of the clavicle and from the acromion process and lower border of the spine of the scapula. Its fibres pass downward, and converge to be *inserted* into the deltoid tubercle of the humerus. Where the muscle passes over the greater tuberosity of the humerus a mucous bursa (**bursa subdeltoidea**) is interposed between it and that prominence.

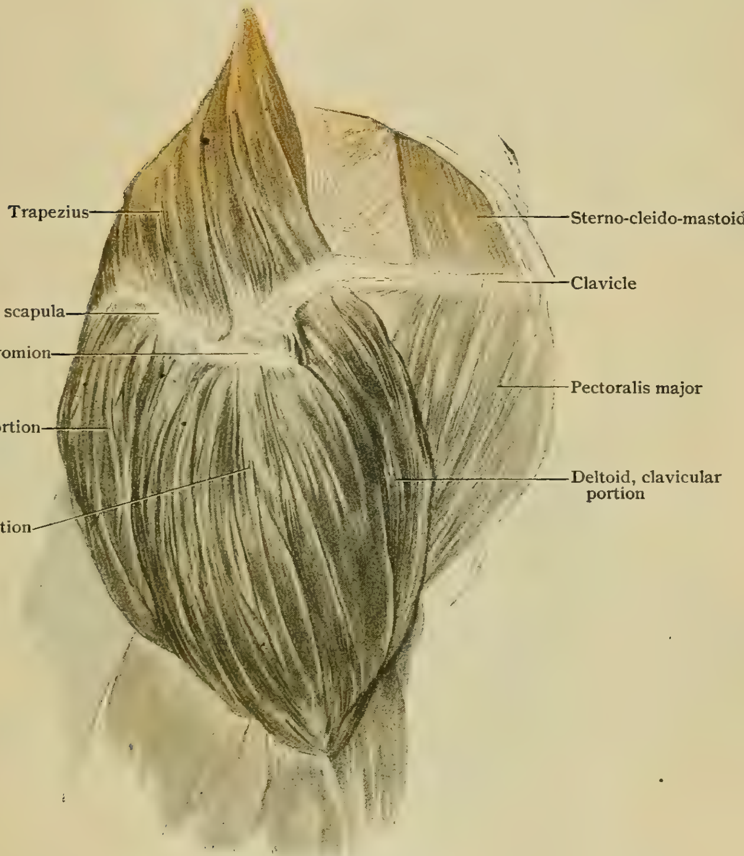
Nerve-Supply.—By the circumflex nerve from the fifth and sixth cervical nerves.

Action.—To abduct the arm to a position at right angles to the body. Further abduction is accomplished by a rotation of the scapula by the contraction of the trapezius and the serratus anterior, whereby the lateral angle of the bone is tilted upward.

Relations.—The deltoid is in relation by its deep surface with the coracoid process and the capsule of the shoulder-joint and with the various muscles attached to or in the neighborhood of these structures. The cephalic vein passes upward along its anterior border.

Variations.—The portion of the deltoid which arises from the clavicle is subject to considerable variation, either being greatly reduced in size or even entirely suppressed, or else being more extensively developed than usual, so that it is in contact or even fused with the clavicular portion of the pectoralis major. It may also be distinctly separated from the remainder of the muscle, and not infrequently a separation of the acromial and spinal portions may also occur, so that the muscle becomes three-headed.

FIG. 562.



Deltoid muscle viewed from side.

Accessory bundles of fibres are occasionally found arising from the fascia infraspinata or from some point along the axillary border of the scapula, and either insert with the deltoid (*m. basio-deltoideus*) or join with the upper part of the muscle, being continued onward as tendinous fibres which pass to the acromion process and lateral extremity of the clavicle (*m. costo-deltoideus*). These fibres represent a portion of the deltoid which in the anthropoid apes arises from the borders of the scapula and in some of the lower mammals forms a distinct muscle.

PRACTICAL CONSIDERATIONS: THE MUSCLES AND FASCIA OF THE AXILLA AND SHOULDER.

The practical relations of the fascia descending to the superior borders of the clavicle and scapula have been sufficiently described (page 551).

Fracture of the Clavicle.—The action of the muscles which move the arm and shoulder and of those attached to the clavicle (page 259) should be considered with reference to the common form of displacement in cases of fracture of the latter bone.

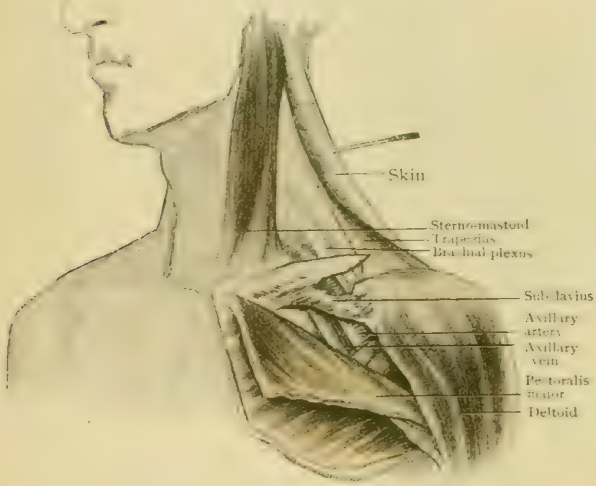
The acromial fragment, as it moves with the shoulder, is the more markedly affected. It is carried *downward* by gravity acting on the upper extremity and aided by the two pectoral muscles and the latissimus dorsi. It is drawn *inward* by

the sternal fibres of the pectoralis major and by all the muscles passing from the trunk to the humerus and scapula. It is *rotated* on a vertical axis so that its inner end points backward and its outer end forward. The cause of the rotation is the action of the two pectorals upon the shoulder and the contraction of the serratus, which (the support of the clavicle having been removed) draws the scapula (and with it the point of the shoulder) inward and forward instead of more directly forward, and so causes an anterior projection of the acromial end of the outer fragment.

Theoretically the inner fragment is displaced upward by the clavicular fibres of the sterno-mastoid, but this action is so strongly resisted by the costo-clavicular (rhomboid) ligament and by the upper and inner fibres of the pectoralis major, as well as by the subclavius, that it is not often productive of much deformity (Fig. 563).

The rationale of the good effect of recumbency with the head slightly elevated is evident. The weight of the upper extremity ceases to drag the outer fragment downward. The vertebral border of the scapula is pressed closely to the thorax by the weight of the trunk. Its outer border, therefore, cannot be drawn forward by the pectorals and serratus, but tends to fall backward and outward, correcting both the rotation and the inward displacement. The slight elevation of the head relaxes the sterno-cleido-mastoid and removes whatever influence it may have in raising the outer end of the inner fragment.

Fig. 563.



Dissection of fracture of middle of clavicle.

Fractures within the limits of the rhomboid ligament at the inner end or within those of the conoid and trapezoid ligaments at the outer end are attended by but little displacement.

Fractures of the scapula have already been dealt with (page 254). Muscular action influences them but little beyond what has been mentioned.

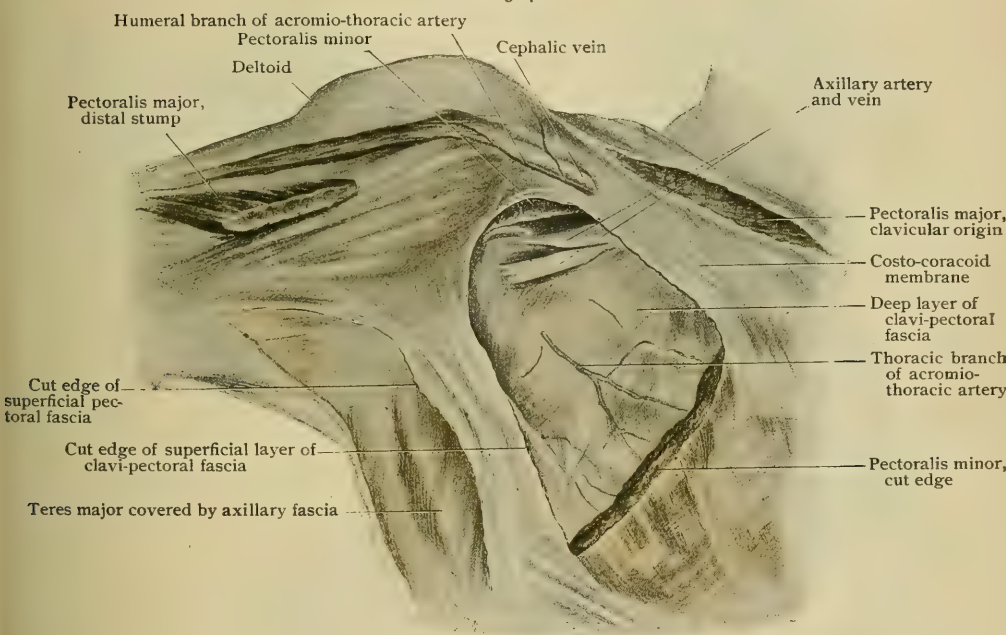
The fascia beneath and connected with the clavicle is of much surgical importance. The superficial fascia of the thorax splits to enclose the breast. The processes which pass from it to the skin (Cooper's "ligamenta suspensoria"), by their involvement and contraction in carcinoma, produce the characteristic adhesion and dimpling of the skin.

The deep pectoral fascia splits to form the sheath of the pectoralis major muscle. Carcinoma of the mamma will usually be found adherent to this layer on the anterior surface of the muscle. Such adhesion can best be demonstrated by attempting to move the tumor and breast in the direction of the pectoral fibres. Motion transverse to that line may, even in cases in which the tumor and muscle are inseparably connected, appear to be free, because the muscle itself is moved on the subjacent structures.

Beneath the deep pectoral fascia an additional sheet, the clavi-pectoral fascia, extends as a continuation downward of the sheath of the subclavius, the two layers of which begin above at the two lips of the subclavian groove on the inferior surface of the clavicle and unite into one layer at the lower edge of the subclavius. This layer is continuous towards the sternum with the deep fascia covering in the first and second intercostal spaces; externally it is attached to the coracoid process; inferiorly, after splitting to enclose the pectoralis minor muscle, it blends with the axillary fascia. The portion of the clavi-pectoral fascia above the upper border of the pectoralis minor is known as the costo-coracoid membrane. It, together with the subclavius

muscle (which it invests), forms the floor of the so-called *superficial infraclavicular triangle*, the roof of which is made by the clavicular fibres of the great pectoral, the base by the anterior fibres of the deltoid, the upper side by the sternal half of the clavicle, and the lower side by a line parallel to the uppermost sternal fibres of the great pectoral. Its apex is at the sterno-clavicular angle of junction. The floor of this space is pierced by the external anterior thoracic nerve, the acromio-thoracic vessels, and the cephalic vein (Fig. 556). Fat containing a few lymphatic glands, often involved in carcinoma of the breast, is found there. It is closed in above by the clavicle, but is continuous below with the space between the two pectoral muscles down to the level where the superficial layer of the deep fascia and the clavi-pectoral fascia (which has invested the pectoralis minor and continued downward as a single layer again) unite at the lower border of the pectoralis major to form the axillary fascia. Effusions of blood or collections of pus occupying this space between the two muscles are therefore prevented from passing upward by the clavicle, forward by the pectoralis major, and backward by the clavi-pectoral fascia and pectoralis minor.

FIG. 564.



Dissection of thoracic wall; pectoralis minor has been partly removed, exposing deep layer of clavi-pectoral fascia.

Consequently they are apt to approach the surface near the anterior axillary margin or in the groove between the great pectoral and deltoid,—*i.e.*, at either the lower border of the sternal portion of that muscle or the upper border of its clavicular fibres.

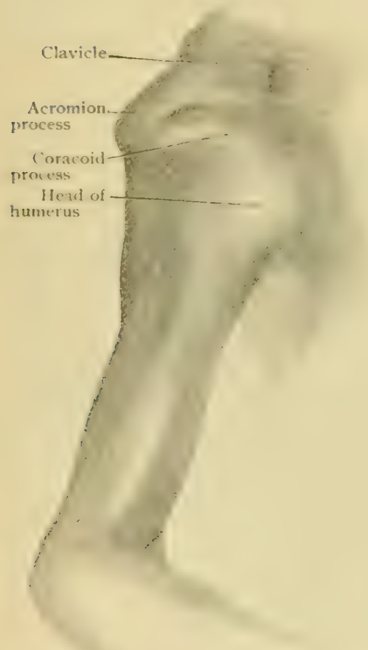
Beneath the costo-coracoid membrane is a region described as the *deep infraclavicular triangle*. Although continuous with the axilla, this space is conveniently studied as a separate region on account of the important structures which it contains and the frequency with which it is invaded by disease. Its floor is formed by the first and second ribs and the intercostal, serratus magnus, and subscapularis muscles. Its apex is at the angle made by the line of the upper border of the small pectoral and that of the clavicle at the coracoid process, those two lines constituting its sides. The base is towards the sternum at the line where the costo-coracoid membrane is fused with the deep fascia over the upper intercostal spaces. Through this triangle pass the axillary, superior thoracic, and acromio-thoracic vessels, the cephalic vein, the external and internal anterior thoracic and long thoracic nerves, and the brachial plexus. It contains fat, with numerous lymphatic glands and vessels. It is obvious

that it is continuous above with the neck and inferiorly with the axilla. The latter space is shut in below by the continuation of the axillary fascia from the lower border of the pectoralis major backward to the latissimus dorsi, outward to the deep fascia of the arm, and inward to the deep fascia of the thorax.

Abscess or effusion of blood, as its progress in all these directions is resisted, may therefore point in the neck, following the vessels and the trunks of the plexus up from the axilla through the deep infraclavicular triangle, to make its appearance above the clavicle.

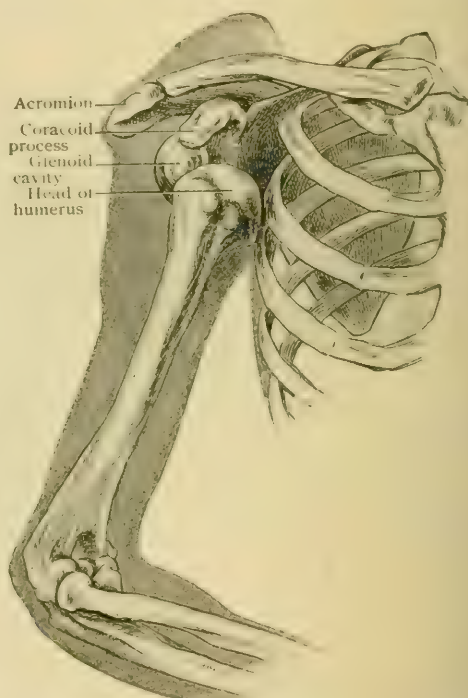
The skin over the fascia at the base of the axilla is thin and richly supplied with hair-follicles and with sebaceous and sudoriparous glands; hence superficial infections are frequent and secondary glandular abscesses are common. The connective tissue of the axillary space is loose and abundant, permitting of free motion of the arm, but also favoring the occurrence of large collections of blood or of pus.

Fig. 565.



Shoulder of subject in which subcoracoid luxation has been produced, showing characteristic deformity.

Fig. 566.



Showing relation of bones in preceding subcoracoid luxation.

The fascia over the scapular muscles—supraspinous and infraspinous fascia—has already been described in reference to caries, necrosis, and abscess (pages 255, 279).

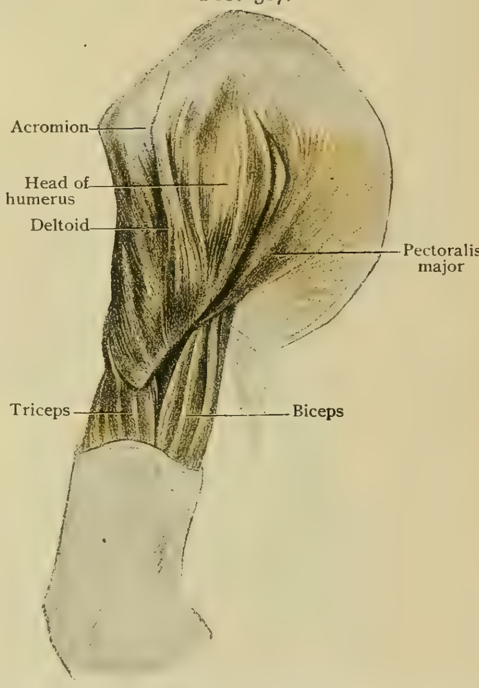
Dislocation of the Shoulder-Joint.—The circumstances that favor or resist dislocation of the shoulder-joint have been enumerated (pages 278, 279), but the anatomical symptoms of that lesion may now be considered with especial reference to the muscles involved. Shoulder dislocation is either subglenoid or subcoracoid in the vast majority of cases, the former being almost invariably the primary form, for reasons previously given (page 278).

A luxation, subglenoid primarily, usually becomes subcoracoid from the continuance of the force producing it, aided strongly by the pectoralis major; hence the subcoracoid is the most common. The subclavicular, in which the head passes farther inward and lies on the second and third ribs beneath the pectoralis major,

and the supracoracoid, in which, owing to fracture of the coracoid or the acromion, the head is displaced upward, are so uncommon that they need merely be mentioned here. The backward (subspinous) luxation is resisted so strongly by the subscapularis, and especially by the long head of the triceps, that it also is a surgical rarity.

In the subglenoid and subcoracoid varieties (Figs. 565, 566) it will be found: 1. That the normal curve of the shoulder is replaced by a straight line, because of (*a*) the absence of the head of the bone and the tuberosities beneath the deltoid; (*b*) the stretching of that muscle. 2. For the same reasons it will be found that (*a*) a ruler applied to the outer side of the arm will touch both the acromion and the external condyle at the same time (Hamilton); and (*b*) the edge of the acromion is unnaturally prominent, while beneath it is a palpable depression instead of the normal resistance of the tuberosities. 3. The elbow is abducted because of the tension of the deltoid. 4. The forearm is flexed on account of the tension of the biceps. 5. The vertical measurement of the axilla is increased (Callaway), because of (*a*) the presence of the head or upper portion of the shaft in the line of measurement; and (*b*) the lowering of the axillary folds (Bryant), the insertions of the pectoralis major and latissimus dorsi being, of course, carried downward with the humerus. 6. The elbow cannot be made to touch the chest-wall while the hand is placed on the opposite shoulder (Dugas), because the head of the bone is held in contact with that wall by the tense muscles and overlying structures, and its lower extremity—the other end of a straight, inflexible axis—cannot be made at the same time to touch at a second point the curve represented by the wall of the thorax. 7. There is rigidity because of the tension or spasm of the muscles moving the humerus, especially of the subscapularis, the deltoid, the supra- and infraspinatus, the biceps, and the coracobrachialis. 8. In the subcoracoid luxation the prominence of the head may be felt beneath the coracoid or outer third of the clavicle where it lies, the anatomical neck resting on the anterior border of the glenoid cavity. There is a little real lengthening,—*i.e.*, the distance between the glenoid surface and the lower end of the humerus must be increased,—but this may be converted into apparent shortening by abduction, which approximates the tip of the acromion and the external condyle. 9. In the subglenoid variety the head may be felt low in the axilla, the anterior wall of which is widened. It rests on the upper part of the outer border of the scapula just below the glenoid cavity. Lengthening is apt to be marked, and, when the arm is adducted somewhat, may exceed an inch. The stretching and "hollow tension" of the deltoid and, therefore, the abduction of the arm are marked. 10. There is usually (*a*) pain from direct pressure upon or from stretching of the brachial plexus, and frequently (*b*) œdema from similar involvement of the axillary vessels.

FIG. 567.



Superficial dissection of preceding subcoracoid luxation, showing muscles after removal of skin and fasciæ.

In all luxations, but especially in the subglenoid and subspinous, the circumflex nerve is apt to be injured; hence obstinate paresis or paralysis of the deltoid is a not infrequent sequel.

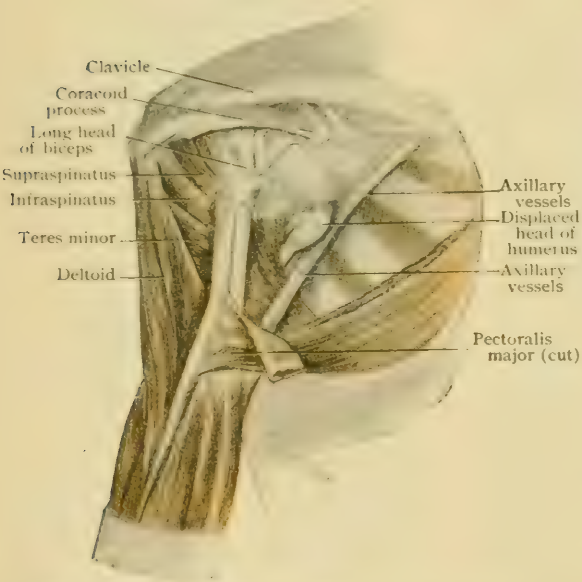
In all methods of reduction of shoulder luxations the humerus is used as a lever, and in all it is desirable to secure fixation of the scapula by means of (*a*) the

weight of the trunk in the supine and recumbent position; (*b*) pressure on the acromion and clavicle; (*c*) the use of a folded sheet placed high in the axilla, so that it presses upon the axillary border in front and the dorsum posteriorly when the two ends are carried across the body and made taut; or (*d*) by dragging on the opposite arm, "which, by making tense the trapezius of the opposite side, provokes contraction of the muscle on the injured side" (Makins).

The use of the heel or foot in the axilla as a fulcrum while manual extension is made—the long arm of the lever, the shaft of the humerus, being carried inward so as to move the short arm, the head, outward—requires no anatomical explanation.

Kocher's method (applicable especially to subcoracoid luxation) is more complex in its mode of action. There is some difference of opinion as to its exact mechanism, but it is safe to say that in its various stages it acts approximately as follows. 1. The elbow is flexed, relaxing the biceps, and the arm is pressed closely to the side, making tense the untorn posterior portion of the capsule extending between the posterior lip of the glenoid fossa and the under and back part of the neck of the humerus. This portion of the capsule and the tendons of the posterior scapular muscles are drawn tightly across the glenoid fossa. 2. The arm is rotated outward until the forearm is parallel with the transverse axis of the body, the hand pointing directly outward. This rolls the head of the bone outward on the tense portion of the capsule, which is partly wound, as it were, upon the neck, and at the same time relaxes the scapular tendons and removes them from the fossa. 3. The elbow is raised until the arm is parallel with the antero-posterior axis of the body. This relaxes the anterior fibres of the deltoid, the coraco-brachialis, and the upper portion of the capsule, and perhaps widens the space between the margins of the rent, although no obstacle to reduction is usually met with there. The lower portion of the capsule is still tense. 4. Rotation inward on this portion as a fulcrum now moves the articular face of the head towards the comparatively free glenoid cavity and relaxes the subscapularis; as the elbow is then lowered in adduction the lower capsular segment relaxes and the head re-enters through the rent by which it originally emerged. These details can be worked out satisfactorily in experimental luxations on the cadaver, and have apparently been demonstrated as to the main points by Farabœuf, Helferich, and others.

Fig. 568.



Deeper dissection of preceding subcoracoid luxation, showing displacement of head of humerus and muscles involved.

Recurrent or "habitual dislocation"—*i. e.*, dislocation occurring from trifling causes, such as abduction of the arm—may be a remote result of the rupture or forcible separation of the tendons of the supra- and infraspinatus muscles from the capsule of the joint, with rupture of the capsule at its upper portion, and the formation of a free communication between the joint-cavity and that of the subcoracoid bursa (Jössel, quoted by Stimson). It is, however, usually due to the injury to the capsule and to the weakness of the shoulder muscles resulting from the original accident.

Bursæ.—The large subacromial bursa and the subdeltoid bursa have been described in relation to their possible enlargements (page 279). The subscapular bursa

and the bursa beneath the infraspinatus often communicate with the shoulder-joint, and disease of the latter may spread to them.

An infraserratus bursa has been described (Terrillon), situated between the inferior scapular angle and the chest-wall. Its enlargement gives rise to friction-like crepitation or creaking, which has been mistaken for fracture of ribs or scapula or for an arthritis of the shoulder. Nancrede says that this symptom is due to (*a*) an exostosis on the ribs or scapula which has caused such atrophy of the subscapular and serratus magnus muscles as to allow the two bony surfaces to come in contact; or (*b*) a localized projection of the ribs due, for example, to a post-pleuritic contraction of the chest, and with the same muscular atrophy; or (*c*) a primary atrophy of the muscles, as in ankylosis of the scapulo-humeral joint, which will admit of the normal scapula and ribs becoming apposed. This latter condition especially causes increased movements of the scapula over the thoracic wall and favors the development of this bursa.

THE BRACHIAL MUSCLES.

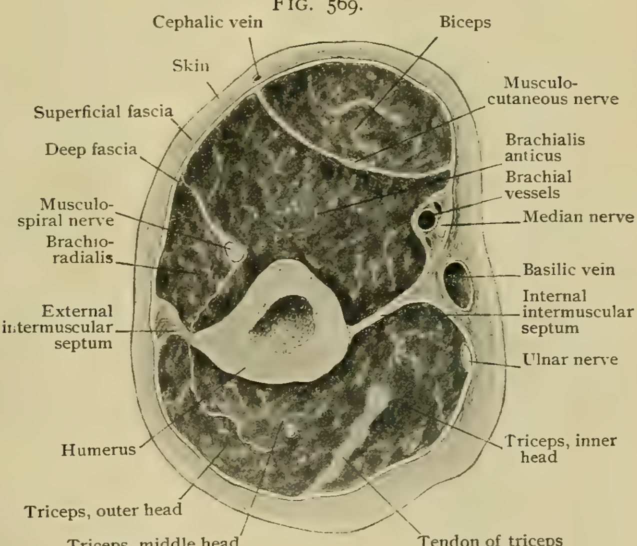
Pre-Axial.	Post-Axial.
1. Biceps	1. Triceps.
2. Brachialis anticus.	2. Anconeus.

The brachial group includes those muscles which act primarily upon the forearm and form the muscular substance of the arm. Some of them, however, take origin in whole or in part from the pectoral girdle and thus have some effect on the movements which occur about the shoulder-joint, although their principal action is upon the forearm.

The Brachial Fascia.—The deep layer of the fascia of the arm forms a complete investment of the muscles of the brachial region. Above it passes over into the thin fascia covering the deltoid muscle, and medially it becomes continuous with the axillary fascia, while below it is continuous with the fascia of the forearm, adhering firmly to the periosteum covering the subcutaneous portions of the humerus and the olecranon process, and being reinforced by tendinous prolongations from the biceps and triceps muscles.

From its lateral and medial surfaces it sends sheet-like prolongations inward to be attached to the humerus. These sheets, termed the *intermuscular septa*, are of considerable strength and give attachment to adjacent muscles. They pass to the humerus between the lateral and medial borders of the triceps and the remaining muscles of the arm, and it is to be noted that, while the medial or inner septum marks the boundary between the pre-axial and post-axial muscles, this is not the case with the lateral or external septum. In the lower part of their extent the septa are attached to the supracondylar ridges of the humerus and terminate at the condyles, a number of post-axial muscles of the forearm arising from the outer condyle anterior to the external septum.

Fig. 569.



Section across right arm in lower third.

A number of subcutaneous bursæ occur between the integument and the brachial fascia in those regions in which the fascia is adherent to the subjacent periosteum covering so-called subcutaneous portions of the skeleton. Thus there is a

bursa acromialis over the acromion process of the scapula, a *bursa olecrani* over the olecranon process of the ulna, and a bursa may occur over each condyle of the humerus.

(*a*) THE PRE-AXIAL MUSCLES.

1. Biceps (Figs. 560, 570).

Attachments.—The biceps (**m. biceps brachii**), as its name indicates, takes origin by two heads. The **long head** *arises* from the upper border of the glenoid cavity of the scapula by a slender round tendon, which traverses the cavity of the shoulder-joint invested by the synovium and then bends downward into the bicipital groove (**intertubercular sulcus**) of the humerus, accompanied by a prolongation of the joint capsule (**vagina mucosa intertubercularis**), and then, becoming muscular, unites with the **short head,** which *arises* from the tip of the coracoid process of the scapula in common with the coraco-brachialis. By the union of the two heads a strong muscle is formed which descends in front of the humerus and a short distance above the elbow-joint passes over into a flat tendon, which is continued downward to be *inserted* into the tuberosity of the radius, a mucous bursa (**bursa bicipitoradialis**) being interposed between the anterior surface of the tuberosity and the tendon. Some of the fibres of the muscle, instead of passing into the tendon, are continued into a flat tendinous expansion, the *semilunar* or *bicipital fascia* (**lacertus fibrosus**), which passes downward and medially to become lost in the fascia of the forearm.

Nerve-Supply.—By the musculo-cutaneous nerve from the fifth and sixth cervical nerves.

Action.—To flex the forearm on the brachium, and when the forearm is in pronation to supinate it. It will also act to a slight extent in movements of the arm at the shoulder-joint, assisting the coraco-brachialis in drawing the arm forward.

Relations.—The biceps is crossed on its ventral surface by the tendon of the pectoralis major and is covered above by the lateral portion of the deltoid. Deeply it is in relation with the humerus, the brachialis anticus, and the supinator. Upon its inner side lie the coraco-brachialis above and below, in the groove between it and the triceps (**sulcus bicipitalis medialis**), the brachial vessels, and the median nerve.

Variations.—The biceps presents numerous variations. Its long head is occasionally wanting, but more frequently additional heads occur. Of these the most frequent, occurring in something over 10 per cent. of cases, is a head which arises from the medial surface of the humerus, between the insertions of the deltoid and coraco-brachialis. Other heads may arise from the external tuberosity of the humerus or from the outer border of that bone, between the deltoid and brachio-radial muscles.

2. Brachialis Anticus (Fig. 571).

Attachments.—The brachialis anticus (**m. brachialis**) occupies the anterior surface of the lower part of the humerus and is for the most part covered by the biceps. It *arises* from the intermuscular septa and the anterior surface of the humerus immediately below the insertion of the deltoid, which it partly surrounds. It passes downward, and the fibres converge to a short tendon which is *inserted* into the anterior surface of the coronoid process of the ulna.

Nerve-Supply.—The main mass of the muscle is supplied by branches from the musculo-cutaneous nerve. The fibres which arise from the lateral intermuscular septum and are covered by the brachio-radialis are supplied by a branch from the musculo-spiral nerve. The nerve-fibres come in both cases from the fifth and sixth cervical nerves.

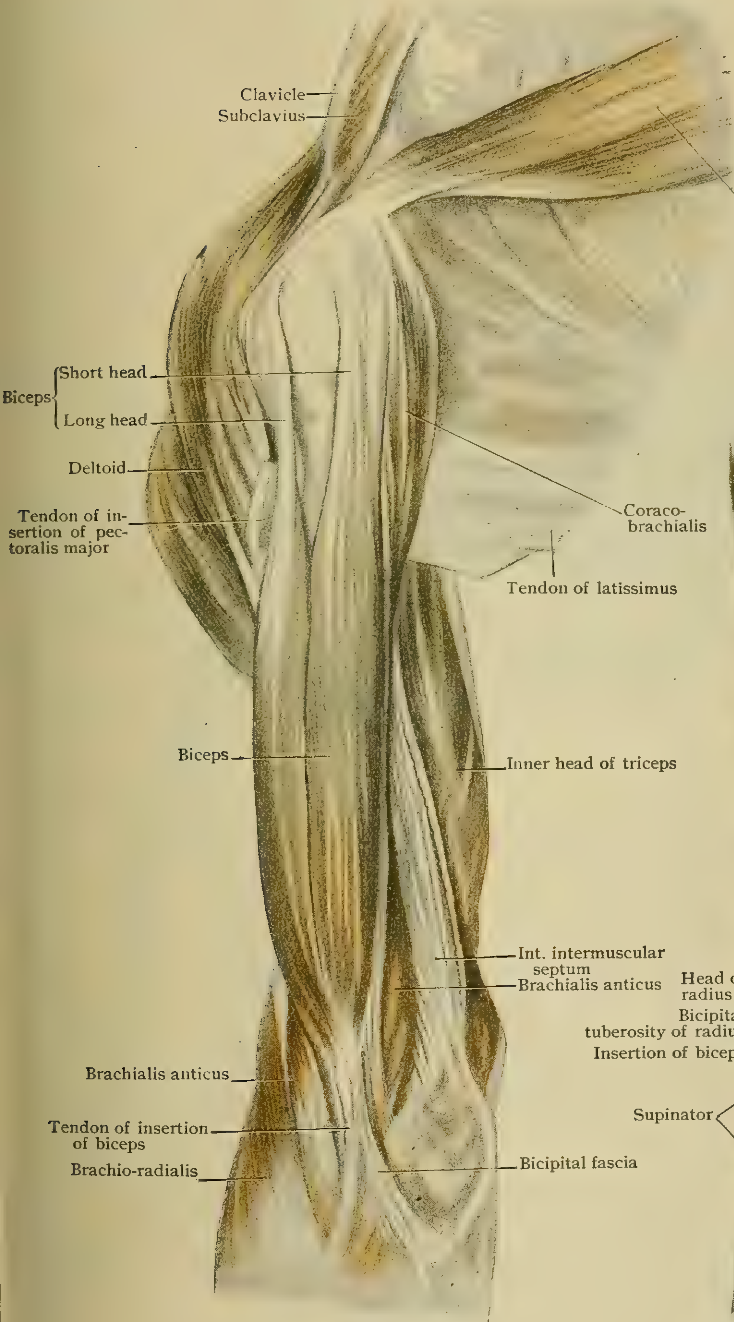
Action.—To flex the forearm.

Variations.—The nerve-supply shows the brachialis anticus to be a composite muscle the major portion of which is derived from the pre-axial muscle-sheet, while the lateral portion of it comes from the post-axial sheet. In correspondence with this derivation of the muscle, its lateral portion is occasionally separate from the rest and may terminate below on the fascia of the forearm or on the radius. A longitudinal separation of the pre-axial portion of the muscle may also occur, and it seems probable that the most frequently occurring third head of the biceps (see above) is a derivative of this portion of the brachialis.

The *epitrochleo-anconeus* is a small, usually quadrangular muscle which is present in about 25 per cent. of cases. It arises from the posterior surface of the inner condyle of the humerus

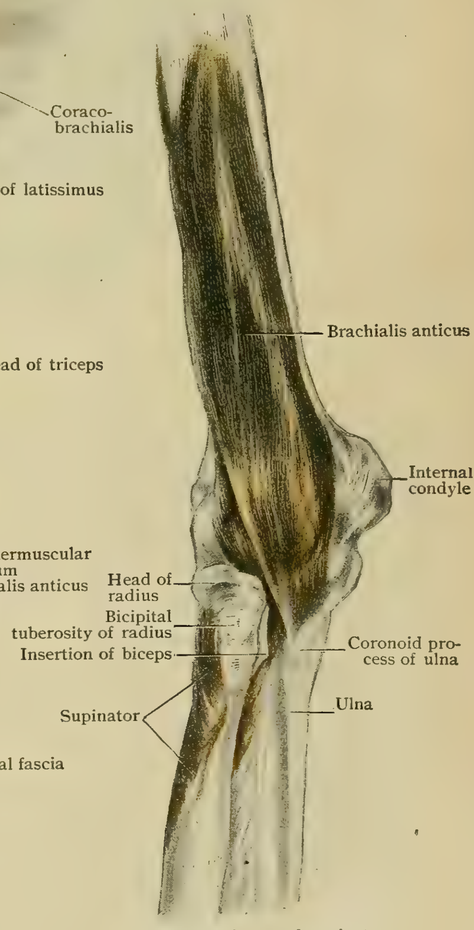
and passes downward and laterally to be inserted into the external surface of the olecranon process of the ulna. Notwithstanding its position upon the posterior surface of the arm, it is a

FIG. 570.



Muscles of anterior surface of arm.

FIG. 571.



Brachialis anticus and supinator, seen from in front.

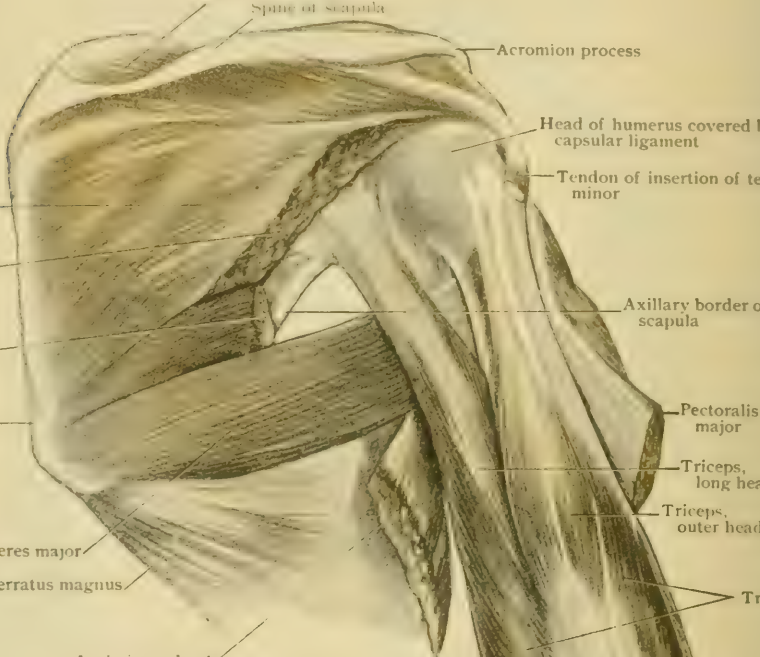
derivative of the pre-axial muscle-sheet and is supplied by the ulnar nerve, whose main stem, as it passes down between the olecranon and the inner condyle, is covered by the muscle. When absent, the muscle is represented by a strong fibrous band.

(b) THE POST-AXIAL MUSCLES.

1. TRICEPS (Figs. 570, 572).

Attachments. The triceps (m. triceps brachii) is a strong muscle which occupies the entire dorsal surface of the arm. It *arises* by three heads. The scapular or

FIG. 572.



Triceps and posterior scapular muscles; portions of infraspinatus and teres minor cut away.

long head takes its origin by a tendon from the infraglenoid tuberosity of the scapula; the inner or **medial head,** from the posterior (dorsal) surface of the humerus and from both intermuscular septa below and medial to the groove for the musculo-spiral nerve; and the outer or **lateral head,** from the external intermuscular septum and the posterior surface of the humerus above and lateral to the groove for the musculo-spiral nerve. The three heads unite to form a strong, broad tendon which is *inserted* into the olecranon process of the ulna. The common tendon of insertion begins as a broad aponeurosis upon the anterior surface of the long head, the fibres of which are attached to the upper border and the upper part of the posterior surface of the aponeurosis. The fibres of the lateral head are attached to the lateral border of the aponeurosis, while those of the medial head, which is much stronger than the lateral one, pass to its anterior surface.

Nerve-Supply.—By the musculo-spiral nerve from the sixth, seventh, and eighth cervical nerves.

Action.—To extend the forearm on the upper arm and to draw the entire arm backward.

Variations.—The triceps occasionally possesses an additional head arising either from the coracoid process of the scapula or from the capsule of the shoulder-joint.

2. Anconeus (Fig. 581).

Attachments.—The anconeus is a short muscle which *arises* from the posterior surface of the external condyle of the humerus. Its fibres diverge to form a triangular sheet which is *inserted* into the upper part of the posterior surface of the ulna and into the outer surface of the olecranon process.

Nerve-Supply.—By the musculo-spiral nerve from the seventh and eighth cervical nerves.

Action.—To assist the triceps in extending the arm.

PRACTICAL CONSIDERATIONS: MUSCLES AND FASCIA OF THE ARM.

The deep fascia of the arm, continuous above with that over the deltoid and with the clavi-pectoral fascia, closely embraces all the muscular structures and resists the outward passage of subfascial collections of blood or pus, which therefore, under the influence of gravity, tend for a time to follow the intermuscular spaces downward. Œdema and swelling above the elbow are thus not uncommon as a result of disease or injury at a higher level. Blood or pus may reach the surface by following the structures that pierce the fascia,—viz., the basilic vein and the internal and external cutaneous nerves. The ecchymosis after fracture sometimes takes this course. The intermuscular septa (page 585) divide the space enclosed by the brachial aponeurosis into an anterior and a posterior compartment extending from the level of the deltoid and coraco-brachialis insertions to that of the two condyles. They, too, have some effect in limiting effusions, but the latter, especially if due to infection, can readily pass from one space to the other by following the musculo-spiral nerve or the superior profunda artery through the outer septum, or the ulnar nerve, inferior profunda artery, or anastomotica magna through the inner septum.

In selecting a method of amputation through the arm it should be remembered that above the middle most of the muscles that it would be necessary to divide are free to retract,—*i.e.*, the deltoid, the long head of the triceps, the coraco-brachialis, and the biceps. Below the middle the biceps is the only muscle unattached. In the former situation, therefore, the circular method is apt to lead to a "conical stump" from the too free retraction of the flaps and from the activity of the upper humeral epiphysis (page 272). In amputation just above the elbow the circular method is applicable, but the incision should be a little lower at the antero-internal aspect of the limb to allow for the greater retraction in the bicipital region.

Inward dislocation of the tendon of the long head of the biceps muscle has probably occurred from direct violence as an uncomplicated lesion in a few cases. The symptoms are said to be (White): (*a*) the recognition of the bicipital groove empty; (*b*) inward rotation due to the pressure of the tendon on the lesser tuberosity and on the tendon of the subscapularis; (*c*) adduction of the humeral head, leaving a slight depression beneath the tip of the acromion; (*d*) obvious tension along the inner edge of the biceps muscle when the forearm is extended; (*e*) diminution in the vertical circumference of the shoulder; and (*f*) shortening of the distance between the acromion and external condyle; both of the last two symptoms are due to the elevation of the humeral head under the influence of the deltoid, the supraspinatus, and the clavicular fibres of the pectoralis major, that of the biceps tendon being withdrawn. These and other symptoms of this lesion (although it is extremely rare) should be studied in connection with the anatomy of the muscles involved, as an aid in elucidating their action.[1]

Rupture of the biceps tendon has always been caused by violent muscular action, and is usually accompanied either by the sudden appearance of a more or less firm tumor on the front of the arm or by complete relaxation and flabbiness of the whole muscle. The symptoms mentioned as characteristic of dislocation of the tendon have not been noted in any recorded case of rupture, with the exception of those due to the elevation of the head of the humerus.

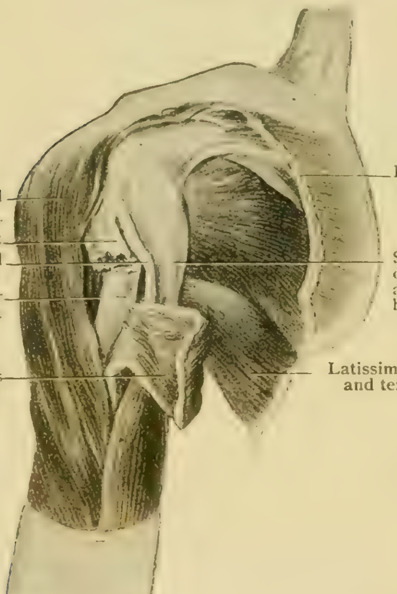
[1] J. William White: American Journal of the Medical Sciences, January, 1884.

Fractures of the humerus are much influenced by muscular action, although the controlling force in the production of the deformity is often that which causes the fracture.

In fracture of the tuberosities the theoretical displacement is upward and backward for the greater tuberosity under the action of the supra- and infraspinatus and teres minor, and forward and inward for the lesser tuberosity, which is supposed to be drawn in that direction by the subscapularis. The injury is extremely rare; the clinical signs are obscure. Increased breadth of the shoulder, localized tenderness and disability, occurring after the application of direct force or after violent action of the shoulder muscles, would be suggestive; recognition of a preternaturally mobile or displaced fragment would be conclusive; but the X-rays will usually be essential.

In fracture of the surgical neck of the humerus—*i.e.*, between the tuberosities and the insertions of the axillary muscles—and in separation of the upper epiphysis the fragments are similarly influenced by muscular action. The upper fragment is held in place, is a little elevated, and is obliquely tilted by the supra- and infraspinatus, subscapularis, and teres minor. The upper end of the lower fragment is drawn towards the chest-wall by the pectoralis major, latissimus dorsi, and teres major. Their action may be aided by that of the deltoid, which may fix the middle of the bone so that it acts as a fulcrum, or may actually abduct the elbow. The biceps, triceps, and coraco-brachialis and deltoid draw the lower fragment upward, causing shortening (Fig. 573).

FIG. 573.



Dissection of fracture of surgical neck of humerus.

Epiphyseal disjunction may be suspected if (*a*) the patient is a child or an adolescent; (*b*) the anterior projection of the upper end of the lower fragment is at an unusually high level,—*i.e.*, about that of the coracoid; (*c*) the crepitus is muffled; (*d*) the shortening is slight (page 272). The application of the tests mentioned above (page 583) will distinguish this lesion from luxation of the shoulder, which, moreover, is very rare before adult life (page 306).

In fracture of the shaft of the humerus between the insertions of the axillary muscles and that of the deltoid the upper fragment is drawn inward by the former muscles; the lower fragment is drawn upward by the biceps, triceps, and coraco-brachialis, and upward and outward by the deltoid (Fig. 573).

In fracture just below the deltoid insertion that muscle acts to such advantage in abducting the upper fragment as to counteract the pull of the axillary muscles in the contrary direction. The relation of the fragments will therefore chiefly depend upon the direction of the line of fracture; the shortening, under the influence of the biceps, triceps, and coraco-brachialis, will depend on its degree of obliquity. In this fracture it is sometimes necessary to dress the arm in abduction to overcome the deltoid contraction.

In fracture just above the condyles (page 273) the line of fracture is usually oblique from above downward and forward (Fig. 288). The short lower fragment will be drawn upward by the biceps and triceps and backward by the latter muscle.

The lower end of the upper fragment will then arrest flexion of the forearm by contact, or may puncture the brachialis anticus, the bicipital fascia, and even the skin.

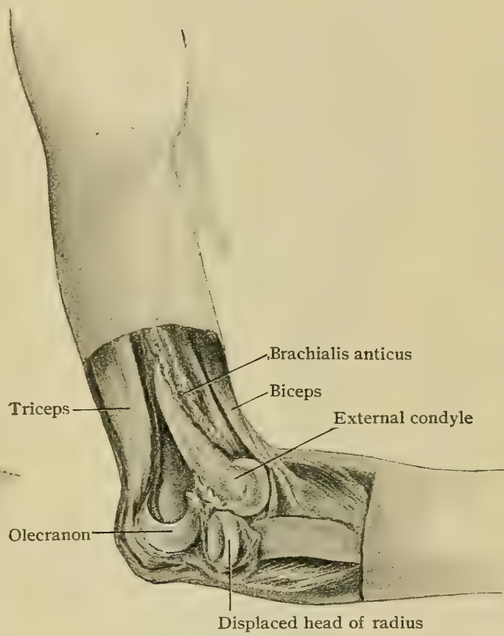
The diagnosis of this fracture from luxation of the elbow (Fig. 575) can be made by (*a*) the recognition of the relations of the three bony points,—the tips of the two condyles and of the olecranon (page 306); (*b*) the presence of crepitus; (*c*) the disappearance of the deformity on extension and counterextension, and, usually, its reappearance when extension is discontinued; and (*d*) the greater freedom of extension of the forearm on the arm in fracture; flexion may be limited, as above mentioned, by the contact of the upper fragment with the forearm at the bend of the elbow and other points; (*e*) the arm is shortened in fracture; the forearm in dislocation.

In separations of the lower humeral epiphysis (page 273) (*a*) the patient is a child or an adolescent; (*b*) there is muffled crepitus; (*c*) the lower end of the upper

FIG. 574.

Posterior luxation of elbow of right side.

FIG. 575.



Dissection of preceding luxation, showing position of bones.

fragment has greater breadth and is more rounded than in fracture; (*d*) the line of separation is nearer the end of the bone, and the anterior projection of the diaphysis is on a level with the fold of the elbow; in fracture it is usually above it (Poland).

Condylar fractures have been described (page 273), but it may be mentioned here that the elevation of the internal condyle, if not corrected, causes the line of the joint to incline inward instead of outward. If union takes place in that malposition, the so-called "gun-stock deformity," or "cubitus varus" (in which the "carrying angle" of the forearm with the arm is obliterated or changed to a similar angle opening inward) results.

The bursæ about the elbow have been described (page 307).

THE ANTIBRACHIAL MUSCLES.

The muscles which belong to this group act primarily upon the bones of the forearm or of the carpus and constitute the muscular substance of the forearm. Some of them, however, have undergone a secondary extension into the hand and act as

flexors or extensors of the digits, this extension being due in some cases to the differentiation of the fascia of the hand into tendons continuous with those of the antibrachial muscles, in other cases to end-union of antibrachial and hand muscles. It will be convenient, however, to regard the long flexors and extensors of the digits, formed in this way, as antibrachial muscles.

Comparatively studied, an arrangement of the antibrachial muscles in distinct layers is clearly perceivable, three layers being found in the pre-axial and two in the post-axial muscles. In both cases the superficial layer takes its origin from the humerus, while the remaining layers are attached above to the bones of the forearm. Secondary adaptations have in some cases interfered with the distinctness of the layers, but the primary conditions will be taken as the basis for the classification of the muscles.

The **antibrachial fascia** completely invests the muscles of the forearm and is the downward continuation of the brachial fascia. It is especially strong upon the dorsal surface of the forearm, where it is attached to the olecranon process and the entire length of the posterior border of the ulna, and anteriorly it is strengthened in its upper part by the fibres of the semilunar fascia of the biceps. At the wrist it is attached to the bones of the forearm and carpus, and becomes thickened by transverse fibres to form the dorsal and volar carpal ligaments.

The *anterior annular ligament* (**ligamentum carpi volare**) lies on the anterior surface of the wrist, covering the flexor muscles in that region (Fig. 577). Laterally and medially it is connected with the dorsal ligament. This, the *posterior annular ligament* (**ligamentum carpi dorsale**), is a stronger transverse band on the posterior surface of the wrist, and is attached laterally to the outer surface and to the styloid process of the radius, and passes inward and slightly downward to the styloid process of the ulna and to the pisiform and cuneiform bones, making attachments to the ridges on the posterior surface of the radius and ulna and thus converting the six intervening grooves into canals which lodge the tendons of the long extensor muscles (Fig. 579). Beginning at the radial side, the first canal transmits the tendons of the extensor ossis metacarpi pollicis and the extensor brevis pollicis ; the second, the tendons of the two extensores carpi radiales ; the third, that of the extensor longus pollicis ; the fourth, those of the extensor communis digitorum and the extensor indicis ; the fifth, that of the extensor minimi digiti ; and the sixth, that of the extensor carpi ulnaris. Each of the canals is lined by an independent synovial membrane.

(*a*) THE PRE-AXIAL MUSCLES.

(*aa*) The Superficial Layer.

1. Pronator radii teres.
2. Flexor carpi radialis.
3. Palmaris longus.
4. Flexor carpi ulnaris.
5. Flexor sublimis digitorum.

1. Pronator Radii Teres (Fig. 576).

Attachments.—This muscle (**m. pronator teres**), thick and band-like, *arises* by two heads (*a*) from the inner condyle of the humerus, the adjacent intermuscular septa, and the deep fascia, and (*b*) from the medial border of the coronoid process of the ulna. It passes downward and laterally and is *inserted* into about the middle of the outer surface of the radius. The median nerve passes downward between the two heads.

Nerve-Supply.—By the median nerve from the sixth cervical nerve.

Action.—To pronate and flex the forearm.

Variations.—The pronator teres is formed by a combination of portions from the superficial and deep layers of the forearm musculature, the condylar head representing the superficial portion and the coronoid head the deep one. In the lower mammals the pronator quadratus frequently extends well up towards the elbow-joint, and the coronoid head of the pronator teres represents the uppermost portion of this muscle, its lower portion persisting as the pronator quadratus. Not infrequently the coronoid portion of the muscle is completely separate from the condylar head, or it may be rudimentary or represented only by a connective-tissue

band. The entire muscle is sometimes incompletely separated from the neighboring muscles of the superficial layer, receiving accessory heads from the palmaris longus or the flexor sublimis digitorum.

2. Flexor Carpi Radialis (Fig. 576).

Attachments.—The flexor carpi radialis *arises* from the inner condyle of the humerus, by a tendon common to it and the neighboring muscles of the superficial layer, from the adjoining intermuscular septa and the deep fascia. It passes downward and slightly laterally and is *inserted* into the bases of the second and third metacarpal bones.

Nerve-Supply. — By the median nerve from the sixth cervical nerve.

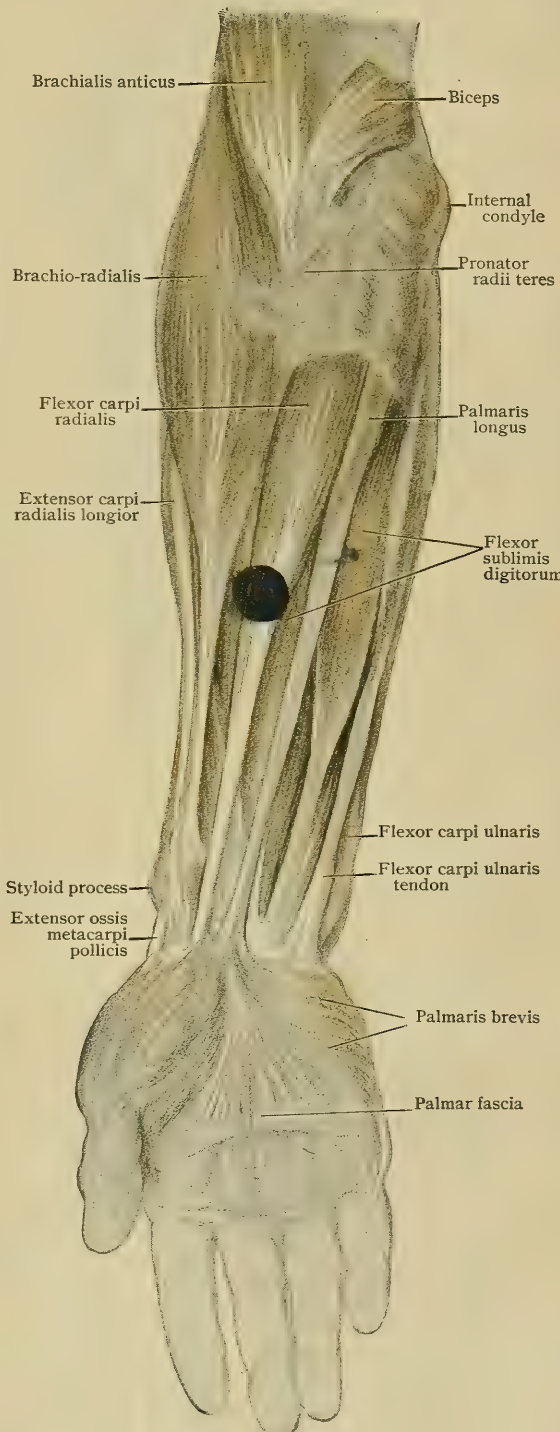
Action.—To flex the hand and to assist in pronating the forearm.

Relations.—In its course down the forearm the flexor carpi radialis passes obliquely across the flexor sublimis digitorum and the lower part of the flexor longus pollicis. At the wrist it passes through a special sheath within the superficial part of the anterior annular ligament, and just before its insertion it is crossed by the tendon of the flexor longus pollicis. A bursa (**bursa m. flexoris carpi radialis**) is interposed between the tendon and the base of the second metacarpal bone. Laterally the muscle is in contact above with the pronator radii teres and below with the brachio-radialis, from which it is separated near the wrist by the radial artery.

3. Palmaris Longus (Fig. 576).

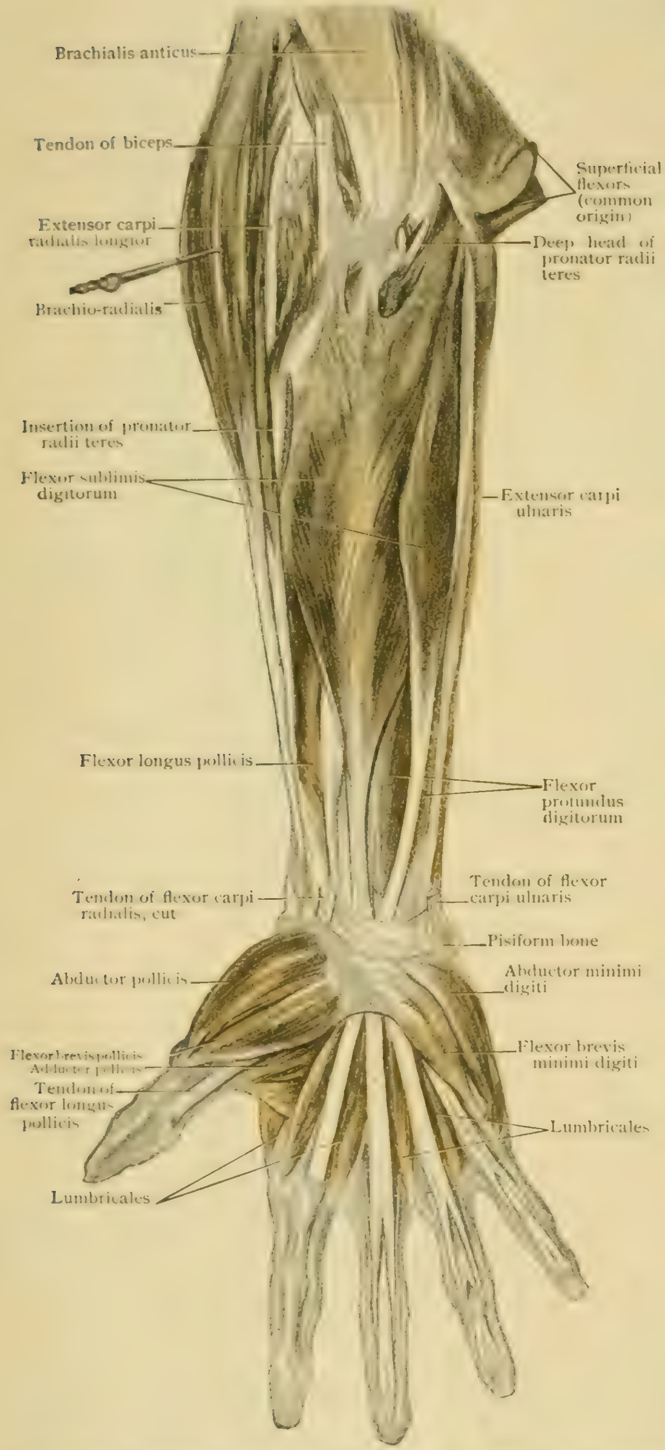
Attachments.—The palmaris longus *arises* with the neighboring superficial muscles by the common tendon from the inner condyle of the humerus, from the adjoining intermuscular septa, and from the deep fascia. It forms a short spindle-shaped belly which is continued into a

Fig. 576.



Superficial dissection of forearm and palm, anterior surface; portion of antibrachial fascia covering origin of superficial muscles has been left in place.

FIG. 577.



Dissection of muscles of forearm and hand, anterior surface; most superficial muscles have been removed.

long, slender tendon that passes in front of the anterior annular ligament of the wrist, and is *inserted* into the palmar fascia.

Nerve-Supply.—By the median nerve from the sixth cervical nerve.

Action.—To tense the palmar fascia and flex the hand.

Variations.—The palmaris longus is a very variable muscle. It is not infrequently absent, and may present various modifications in its structure, being sometimes entirely tendinous, or entirely fleshy, or tendinous above and fleshy below. It is occasionally double.

4. FLEXOR CARPI ULNARIS (Fig. 576).

Attachments.—The flexor carpi ulnaris *arises* from the medial condyle of the humerus in common with the neighboring superficial muscles, from the inter-muscular septa and deep fascia, and also from the posterior surface of the olecranon process, and from the upper part of the posterior border of the ulna by means of an aponeurosis common to it and the flexor profundus digitorum and the extensor carpi ulnaris. It descends along the ulnar border of the forearm and is *inserted* into the pisiform bone, its tendon being continued on to be attached to the hook of the unciform and, often, to the base of the fifth metacarpal bone.

Nerve-Supply.—By the ulnar nerve from the eighth cervical and first thoracic nerves.

Action.—To flex and adduct the hand.

Relations.—By its deep surface this muscle is in relation with the sublimis and profundus digitorum and with the ulnar vessels and nerve. The ulnar nerve and posterior recurrent ulnar artery pass beneath a tendinous band which stretches across between the two heads of the muscle, and towards the wrist the ulnar artery comes to lie along the lateral border of the tendon. A mucous bursa (**bursa m. flexoris carpi ulnaris**) is frequently to be found between the tendon and the upper part of the pisiform bone.

Variations.—The flexor carpi ulnaris frequently passes distally to be inserted into the base of the fifth metacarpal. The conversion of the ulnar head into connective tissue has been observed.

5. Flexor Sublimis Digitorum (Fig. 577).

Attachments.—The superficial flexor (**m. flexor digitorum sublimis**) *arises* from the inner condyle of the humerus in common with the neighboring superficial muscles, from an oblique line on the anterior surface of the radius, and from the tendinous arch extending between these two bony points and beneath which the median nerve and ulnar artery pass. The fibres arising from these origins form four bellies, prolonged below into as many tendons, which at the wrist pass beneath the anterior annular ligament and then diverge towards the bases of the second, third, fourth, and fifth fingers and enter the corresponding digital sheaths. Here each tendon divides over the surface of the first phalanx into two slips, which pass one on either side of the subjacent tendon of the flexor profundus digitorum and partially unite beneath it to be inserted into the base of the second phalanx. Slight tendinous bands, *vincula tendinum*, pass between the tendons of the profundus and the terminal portions of those of the sublimis.

Nerve-Supply.—By the median nerve from the seventh and eighth cervical and first thoracic nerves.

Action.—Primarily to flex the second phalanx of the four medial digits, but a continuation of its action will flex the first phalanges of the same digits and eventually the hand.

Relations.—Superficially the flexor sublimis is covered by the remaining muscles of the superficial layer; deeply it is in relation with the flexor profundus digitorum, the flexor longus pollicis, the ulnar vessels, and the median nerve.

Variations.—Occasionally the portion of the muscle which gives rise to the tendon of the fifth digit appears to be wanting, the tendon arising from the palmar fascia, the anterior annular ligament, or the flexor profundus. An explanation of this anomaly is found in the developmental history of the muscle. In the lower vertebrates the superficial flexor inserts into the palmar fascia, which gives origin to a set of superficial digital muscles whose relations are similar to those of the digital portions of the sublimis tendons. In the mammalia these digital muscles degenerate into tendinous bands, with which the tendon of the antibrachial portion of the muscle becomes continuous. The origin of the tendon for the fifth digit from the palmar aponeurosis or transverse carpal ligament is, therefore, a persistence of a phyletic stage, as is also its origin from the flexor profundus, since in the lower mammals the antibrachial portions of the two muscles are united to form a single mass (page 597).

(*bb*) The Middle Layer.

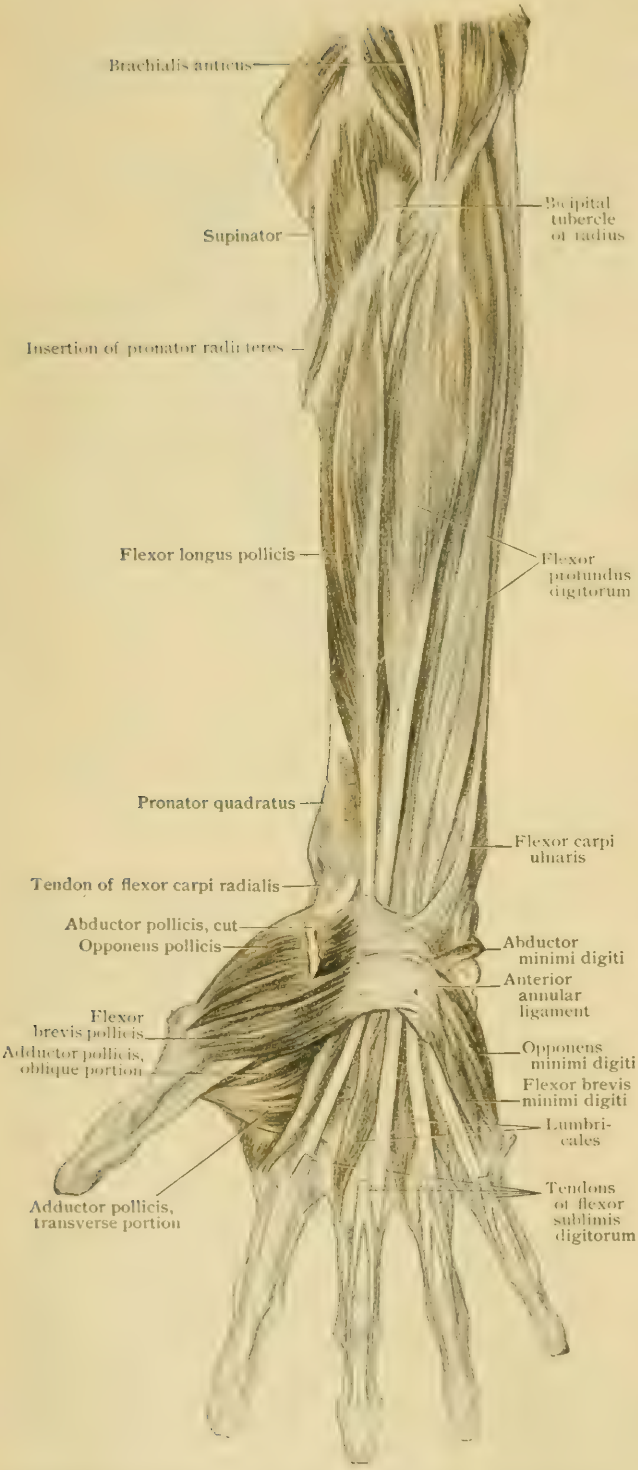
1. Flexor profundus digitorum. 2. Flexor longus pollicis.

1. Flexor Profundus Digitorum (Fig. 578).

Attachments.—The deep flexor (**m. flexor digitorum profundus**) *arises* from the anterior and outer surfaces of the ulna and from the inner half of the interosseous membrane. Its fibres are directed downward, and at about the middle of the forearm are continued into four tendons, which pass beneath the anterior annular ligament along with the tendons of the flexor sublimis to enter the digital sheaths of the second, third, fourth, and fifth fingers. Opposite the first phalangeal joint each tendon passes between the two slips of the corresponding tendon of the flexor sublimis and is *inserted* into the base of the terminal phalanx.

Nerve-Supply.—The lateral half of the muscle is supplied by branches from the anterior interosseous branch of the median nerve and the medial half by the

Fig. 578.



Dissection of muscles of forearm and hand, anterior surface; superficial muscles have been removed.

ulnar; the fibres come from the seventh and eighth cervical and the first thoracic nerves.

Action.—The primary action of the flexor profundus is to flex the terminal phalanges of the second, third, fourth, and fifth fingers, but, continuing its action, it also flexes the remaining phalanges of those digits and finally the hand.

Relations. — In the arm the muscle is covered by the flexor sublimis digitorum and the flexor carpi ulnaris, and has resting upon its anterior surface the ulnar vessels and the median and ulnar nerves. Posteriorly it is in relation to the pronator quadratus and the wrist-joint. In the hand its tendons are covered by those of the flexor sublimis and by the lumbrical muscles; they rest upon the adductor pollicis and interosseous muscles and cross the deep palmar arch.

Variations.—The flexor profundus frequently receives additional slips from the flexor sublimis and may be united to the flexor longus pollicis. A slip which has been termed the *accessorius ad flexorem profundum digitorum* not infrequently occurs, arising from the coronoid process of the ulna and joining with one of the tendons of the profundus. The significance of the variations of the profundus will be considered in connection with those of the flexor longus pollicis.

2. Flexor Longus Pollicis (Fig. 578).

Attachments.—The long flexor of the thumb (**m. flexor pollicis longus**) lies to the lateral side of the flexor profundus digitorum and *arises* from the anterior surface of the radius and the adjacent half

of the interosseous membrane. It usually possesses also an origin by means of a slender slip from the coronoid process of the ulna or the medial epicondyle of the humerus. The muscle-fibres pass into a strong tendon at the middle of the forearm, and this passes downward beneath the lateral part of the annular ligament and extends along the volar surface of the thumb to be *inserted* into the base of its terminal phalanx.

Nerve-Supply.—By the anterior interosseous nerve from the eighth cervical and first thoracic nerves.

Action.—To flex the terminal phalanx of the thumb; continuing its action, it will also flex the proximal phalanx and assist in the flexion of the hand.

Relations.—In the forearm it is covered by the flexor sublimis digitorum, the flexor carpi radialis, and the brachio-radialis, and has resting upon it the radial vessels. Deeply it is in relation with the pronator quadratus and the wrist-joint. In the hand its tendon is covered by the opponens pollicis and the flexor brevis pollicis, and it rests upon the adductor pollicis.

Variations.—The head from the coronoid process or medial epicondyle of the humerus is sometimes absent and the muscle is frequently connected with the flexor profundus digitorum or even fused with it.

Occasionally there arises from the lower part of the anterior and external surfaces of the radius a muscle which has been termed the *flexor carpi radialis brevis*. Its insertion varies somewhat, being sometimes on one of the carpal bones, at other times on either the second, third, or fourth metacarpals, and at others, again, into the transverse carpal ligament. Although associated by name with the flexor carpi radialis, it is more probably a derivative of the deeper layer of the flexor musculature and is supplied by the volar interosseous branch of the median nerve.

The majority of the variations of the flexor longus pollicis and flexor profundus digitorum find an explanation in the historical development of the muscles. In the lowest group of the mammalia, the monotremata, the two muscles are fused with each other and also with the flexor sublimis to form a common long flexor, from the tendon of which the tendons of the flexor sublimis arise. In slightly higher forms this common flexor can be seen to be composed of five portions, which, from their points of origin and relations, may be termed the condylo-ulnaris, condylo-radialis, centralis, ulnaris, and radialis, and as the scale is ascended one finds at first a part of the condylo-ulnaris and later the whole of that portion separating from the common mass and joining the tendons of the sublimis. In still higher forms the centralis and condylo-radialis portions follow the example of the condylo-ulnaris, the flexor sublimis digitorum in man being composed of these portions of the common mass.

The ulnaris and radialis portions remain, as a rule, united and, after the separation of the superficial portions is completed, constitute the flexor profundus. In man and a few other forms the radialis separates from the ulnaris to form the flexor longus pollicis.

The connections which occur between the sublimis, profundus, and flexor longus pollicis are consequently to be regarded as relics of the historical development of the muscles, as the incomplete separation of a common flexor mass.

In the lower terrestrial vertebrata the superficial and deeper layers, corresponding practically to the sublimis and profundus (plus the flexor longus pollicis), are distinct, their fusion in the monotremes being a secondary condition, which forms the starting-point for the differentiation of the mammalian arrangement of the muscles. In these lower forms both layers insert into the palmar aponeurosis, the extension of the deeper layer to the digits being due to the separation of the layer of the aponeurosis to which the deeper muscle-layer is attached and its differentiation into tendons.

It may be added that in the lower vertebrates the palmaris longus is not represented as a separate muscle, and it is to be regarded as a portion of the superficial sheet which has retained its original relations to the palmar aponeurosis, its occasional absence being ascribed to its sharing the history of the flexor sublimis and being incorporated in that muscle.

(*cc*) The Deep Layer.

1. Pronator quadratus.

1. Pronator Quadratus (Fig. 588).

Attachments.—The pronator quadratus is a flat quadrangular sheet extending across between the lower portions of the radius and ulna. It *arises* from the volar surface of the ulna and passes laterally and slightly distally to be *inserted* into the lateral and anterior surfaces of the lower end of the radius.

Nerve-Supply.—By the anterior interosseous branch of the median nerve from the seventh and eighth cervical and the first thoracic nerves.

Action.—To pronate the forearm.

Variations.—The pronator quadratus usually occupies about the lower fourth of the forearm, but it may be considerably reduced or, on the contrary, may extend as high as the middle of the forearm or even higher. It represents the lower portion of a muscle-sheet which extends in some of the lower mammals almost the entire length of the forearm, the upper portion of this sheet being represented, as already pointed out, by the coronoid head of the pronator teres.

(*b*) THE POST-AXIAL MUSCLES.

The post-axial muscles of the forearm may be regarded as consisting of two layers, the more superficial of which arises from the external condyle of the humerus, while the deeper one is attached to the bones of the forearm. As was the case with the pre-axial muscles, constituents of both layers have extended into the hand to act as extensors of the digits.

(*aa*) The Superficial Layer.

1. Brachio-radialis.
2. Extensor carpi radialis longior.
3. Extensor carpi radialis brevior.
4. Extensor communis digitorum.
5. Extensor minimi digiti.
6. Extensor carpi ulnaris.

1. Brachio-Radialis (Fig. 576).

Attachments.—The brachio-radialis, sometimes termed the *supinator longus*, *arises* from the external condylar ridge of the humerus and from the lateral intermuscular septum. Its fibres form a strong muscle which, at about the middle of the forearm, passes into a tendon which is *inserted* into the base of the styloid process of the radius.

Nerve-Supply.—By the musculo-spiral nerve from the fifth and sixth cervical nerves.

Action.—To flex the forearm. If the arm be in a position of complete pronation, it will produce a slight amount of supination.

Relations.—In its upper part it is in contact medially with the brachialis anticus, a portion of whose lateral border it covers, and with the radial nerve. Below it rests upon the upper portion of the extensor carpi radialis longior, the supinator, the pronator teres, the flexor sublimis digitorum, and the radial artery and nerve. It is crossed near its insertion by the tendons of the abductor longus pollicis and extensor brevis pollicis.

Variations.—The brachio-radialis is sometimes wanting. It may be inserted a considerable distance above the base of the styloid process of the radius, a condition characteristic of the lower mammals, or it may pass as far down as the carpal bones or even to the base of the third metacarpal.

2. Extensor Carpi Radialis Longior (Figs. 576, 579).

Attachments.—The longer of the radial carpal extensors (**m. extensor carpi radialis longus**) lies immediately posterior to the brachio-radialis. It *arises* from the lower third of the external supracondylar ridge of the humerus, the external intermuscular septum, and the extensor tendon common to it and the neighboring superficial muscles. About the middle of the forearm it is continued into a tendon which passes beneath the posterior annular ligament in the second compartment, along with the extensor carpi radialis brevior, and is *inserted* into the base of the second metacarpal.

Nerve-Supply.—By the deep division of the musculo-spiral nerve from the sixth and seventh cervical nerves.

Action.—To extend and slightly abduct the hand.

Variations.—The extensor carpi radialis longior is occasionally fused with the extensor carpi radialis brevior. It may send tendinous slips to the first and third metacarpals and to the trapezium.

3. Extensor Carpi Radialis Brevior (Fig. 579).

Attachments.—The shorter radial carpal extensor (**m. extensor carpi radialis brevis**) is fused with the neighboring superficial extensors where it *arises* from the

external condyle of the humerus, from the adjacent intermuscular septa, and from the deep fascia of the forearm. Its fibres converge at about the middle of the forearm into a flat tendon, which passes with the long extensor carpi radialis beneath the posterior annular ligament in the second compartment and is inserted into the base of the third metacarpal, a bursa (**bursa m. extensoris carpi radialis**) being interposed between the tendon and the bone.

Nerve-Supply. — By the posterior interosseous branch of the musculo-spiral nerve from the sixth and seventh cervical nerves.

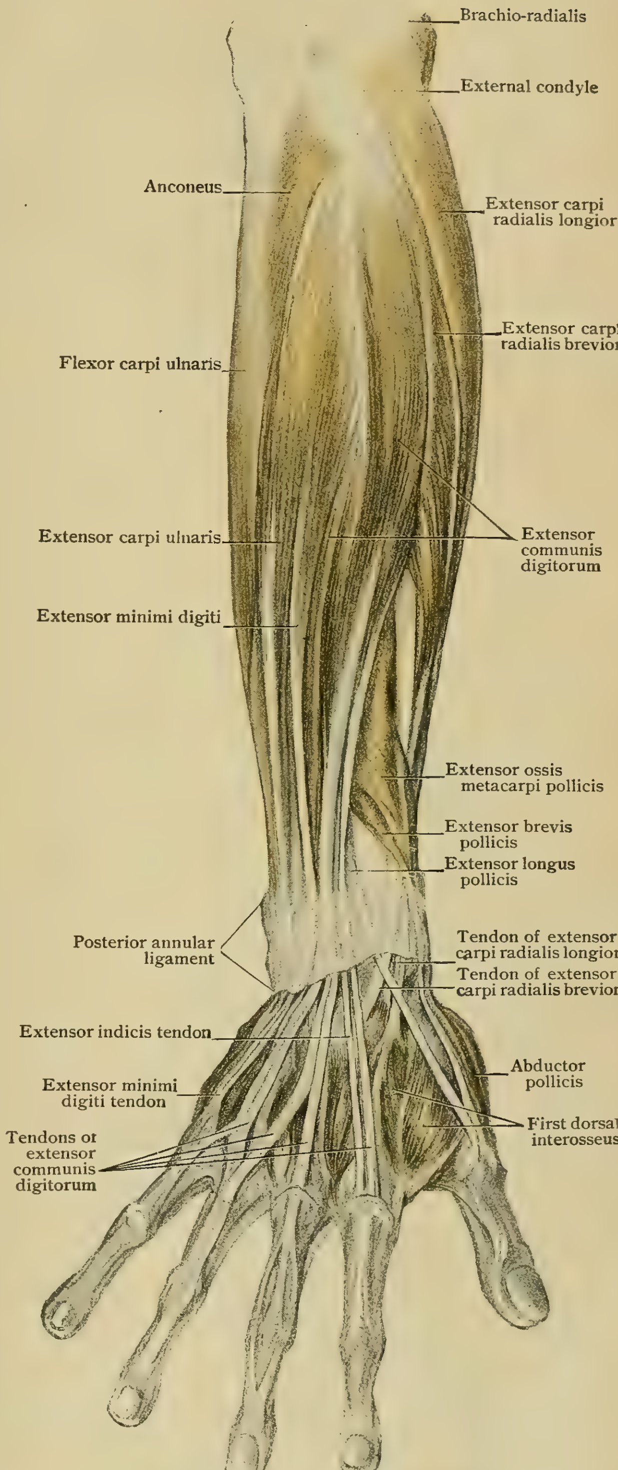
Action. — To extend the hand.

Variations.—It may be fused to a greater or less extent with the extensor carpi radialis longior and may be inserted into the bases of both the second and third metacarpals.

4. EXTENSOR COMMUNIS DIGITORUM (Fig. 579).

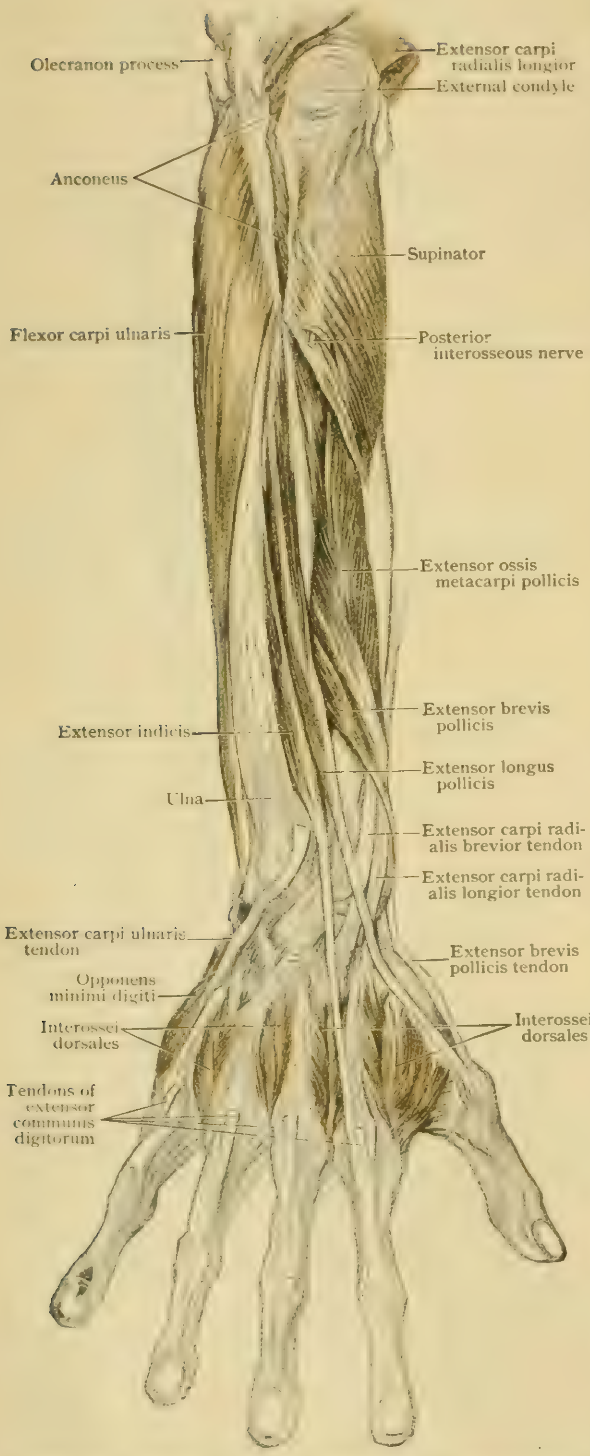
Attachments. — The common extensor of the fingers (**m. extensor digitorum communis**) *arises* in common with the neighboring superficial extensors from the external condyle of the humerus, from the septa between it and the adjoining muscles, and from the deep fascia of the forearm. At about the middle of the forearm its fibres go over into four tendons, which pass through the fourth compartment beneath the posterior annular ligament and diverge to be *inserted* into the bases of the middle and terminal phalanges of the second, third, fourth, and fifth fingers. Just before they pass over the metacarpo-phalangeal joints of their digits the four tendons are usually united by

FIG. 579.



Dissection of posterior surface of forearm and hand, showing superficial extensor muscles.

FIG. 580.



Dissection of posterior surface of forearm and hand, showing deep muscles.

three obliquely transverse tendinous bands (**juncturae tendinum**), the one between the index and median digits being, however, frequently wanting. As each tendon passes upon the dorsum of the first phalanx of its digit it spreads out into a membranous expansion, which receives the insertions of the interosseous and lumbrical muscles and then divides into three more or less well-defined slips. The median slip passes to the base of the second phalanx, while the lateral ones, passing over the first interphalangeal joint, unite over the dorsum of the second phalanx and are inserted into the base of the third or distal phalanx.

Nerve-Supply.—By the posterior interosseous branch of the musculo-spiral nerve from the sixth, seventh, and eighth cervical nerves.

Action.—To extend the phalanges of the second, third, fourth, and fifth fingers and, continuing its action, to extend the hand.

Variations. — The principal variations of the common extensor consist in the absence of one or other of the tendons, usually that to the fifth digit and more rarely that to the second, or else in the occurrence of additional tendons, due to the division of one or more of those typically occurring, certain of the digits then receiving two or even three tendons. Occasionally an additional tendon is present which passes to the thumb to unite with the tendon of its long extensor.

5. EXTENSOR MINIMI DIGITI (Fig. 579).

Attachments.—The extensor of the little finger (**m. extensor digiti quinti proprius**) *arises* in common with the preceding muscle from the lateral epicondyle of the humerus and from the antibrachial fascia. Its tendon passes beneath the posterior annular ligament in the fifth compartment and fuses over the fifth metacarpal

with the tendon of the extensor communis digitorum which passes to the little finger.

Nerve-Supply.—By the posterior interosseous branch of the musculo-spiral nerve from the sixth, seventh, and eighth nerves.

Action.—To extend the little finger.

Variations.—This muscle is sometimes absent, probably remaining incorporated in the extensor communis. Its tendon occasionally sends a slip to the fourth finger.

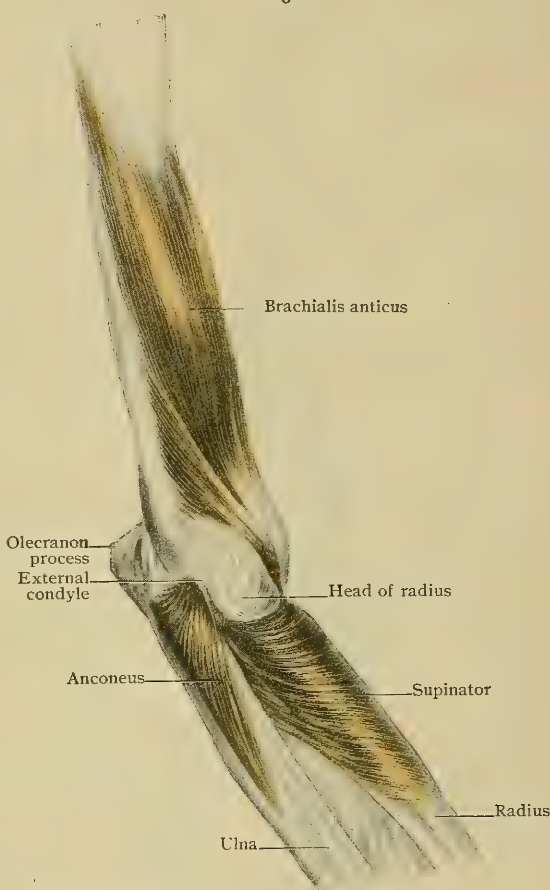
6. Extensor Carpi Ulnaris (Figs. 577, 579).

Attachments.—The extensor carpi ulnaris *arises* in common with the adjacent superficial extensors from the external condyle of the humerus, from the deep fascia, and, usually, from the aponeurosis attached to the posterior border of the ulna common to this muscle, the flexor profundus digitorum, and the flexor carpi ulnaris. Its tendon passes through the sixth compartment beneath the posterior annular ligament and is *inserted* into the base of the fifth metacarpal bone.

Nerve-Supply. — By the posterior interosseous branch of the musculo-spiral nerve from the sixth, seventh, and eighth cervical nerves.

Action.—To extend and adduct the hand.

Fig. 581.



Dissection of arm, showing deep muscles in vicinity of elbow.

Variations.—A fibrous band is often given off from the tendon of the muscle to be inserted somewhere over the fifth metacarpal into the sheath of the tendon of the extensor of the little finger; it has been termed the *m. ulnaris quinti digiti.*

(*bb*) The Deep Layer.

1. Supinator.
2. Extensor ossis metacarpi pollicis.
3. Extensor brevis pollicis.
4. Extensor longus pollicis.
5. Extensor indicis.

1. Supinator (Figs. 580, 581).

Attachments.—The supinator, also termed the *supinator radii brevis*, is a flat triangular muscle which *arises* partly from the outer condyle of the humerus and the orbicular ligament of the elbow-joint, and partly from the upper part of the lateral border of the ulna and the smooth surface beneath the lesser sigmoid cavity of that bone. Its fibres pass obliquely downward and outward, diverging as they go, and are *inserted* into the posterior, lateral, and anterior surfaces of the radius, curving around that bone. The insertion extends downward to about the middle of the radius.

Nerve-Supply.—By the posterior interosseous branch of the musculo-spiral nerve from the sixth cervical nerve.

Action.—To supinate the forearm.

Variations.—The posterior interosseous nerve perforates the supinator and occasionally marks the line of separation of the muscle into two portions, which correspond to the epicondylar and ulnar portions of the muscle. The muscle is indeed a composite one, a portion of it being derived from the superficial extensor layer and the rest of it from the deep layer.

2. Extensor Ossis Metacarpi Pollicis (Fig. 580).

Attachments.—The extensor of the metacarpal bone of the thumb (**m. abductor pollicis longus**) *arises* from the middle third of the posterior surfaces of the ulna, the interosseous membrane, and the radius. It passes downward and laterally, and its tendon passes through the first compartment beneath the posterior annular ligament to be *inserted* into the outer side of the base of the first metacarpal bone.

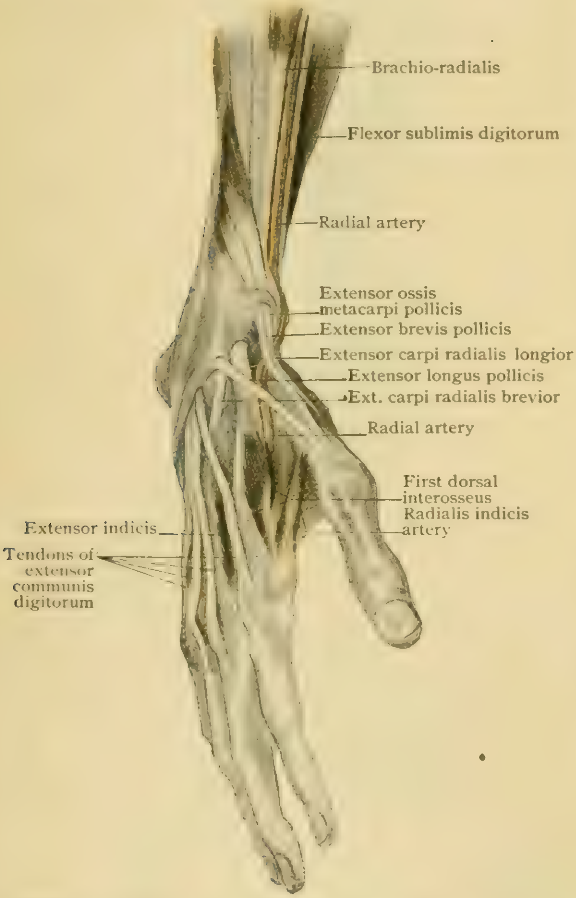
Nerve-Supply.—By the posterior interosseous branch of the musculo-spiral nerve from the sixth, seventh, and eighth cervical nerves.

Action.—To abduct and slightly extend the thumb and, continuing its action, to abduct the hand.

Relations.—It is covered by the muscles of the superficial layer and is crossed obliquely by the dorsal interosseous artery. Below it crosses obliquely the tendons of the extensores carpi radiales and the radial artery.

Variations.—It may be partially or wholly fused with the extensor brevis pollicis. Occasionally it possesses two tendons, one of which may be inserted into the dorsal carpal ligament, the abductor brevis pollicis, or the trapezium.

Fig. 582.



Superficial dissection of hand, viewed from radial side, showing extensor tendons of thumb.

3. Extensor Brevis Pollicis (Fig. 580).

Attachments.—The short extensor of the thumb (**m. extensor pollicis brevis**), also termed the *extensor primi internodii pollicis*, lies along the medial border of the extensor ossis metacarpi pollicis. It *arises* from the interosseous membrane and the posterior surface of the radius, partly under cover of the extensor longus pollicis, and its tendon, after passing with that of the abductor through the first compartment of the posterior annular ligament, is *inserted* into the base of the first phalanx of the thumb.

Nerve-Supply.—By the posterior interosseous branch of the musculo-spiral nerve from the sixth, seventh, and eighth cervical nerves.

Action.—To abduct the thumb and extend its first phalanx.

Relations.—The relations of the muscle are essentially the same as those of the extensor ossis metacarpi pollicis.

Variations.—The extensor brevis and the metacarpal extensor of the thumb are differentiations of a common muscle and show indications of this in their partial or complete fusion. The tendon of the extensor brevis is sometimes continued onward to the terminal phalanx of the thumb or may send a slip to the base of the second metacarpal.

4. Extensor Longus Pollicis (Fig. 580).

Attachments.—The long extensor of the thumb (**m. extensor pollicis longus**), also known as the *extensor secundi internodii pollicis*, is an elongated fusiform muscle lying along the medial border of the extensor brevis pollicis, which it partly covers. It *arises* from the interosseous membrane and posterior surface of the ulna; its tendon passes downward in the third compartment beneath the posterior annular ligament and, crossing over the tendons of the extensores carpi radiales, is *inserted* into the base of the terminal phalanx of the thumb.

Nerve-Supply.—By the posterior interosseous branch of the musculo-spiral nerve from the sixth, seventh, and eighth cervical nerves.

Action.—To extend the terminal phalanx of the thumb and, continuing its action, to extend and at the same time slightly adduct the thumb.

5. Extensor Indicis (Fig. 580).

Attachments.—The extensor of the index-finger (**m. extensor indicis proprius**) lies along the medial border of the extensor longus pollicis. It *arises* from the interosseous membrane and the dorsal surface of the ulna. Its tendon passes, along with the tendons of the extensor communis digitorum, through the fourth compartment beneath the posterior annular ligament, and eventually is *inserted* with the tendon of the common extensor which passes to the index-finger.

Nerve-Supply.—By the posterior interosseous branch of the musculo-spiral nerve from the seventh and eighth cervical nerves.

Action.—To extend the index-finger.

Variations.—The extensor indicis may be wanting, or its tendon may send slips to the third and fourth digits. Occasionally a muscle arises from the ulna, below the origin of the extensor indicis, and passes to the third or fourth finger, forming what has been termed the *extensor digiti medii* (*vel annularis*) *proprius*. This muscle represents an additional portion of the deep extensor layer which normally disappears.

PRACTICAL CONSIDERATIONS: THE FOREARM.

The fascia descending from the arm to the forearm should be studied anteriorly with relation to the expansion known as the bicipital aponeurosis (Fig. 570),—one of the "two inferior tendons of the biceps" of the older anatomists,—which becomes continuous with the deep fascia of the forearm, and thus, through the origin from its under surface of fibres of many of the superficial muscles of that region, associates their action with that of the biceps itself. Partly for this reason injuries and diseases affecting the bicipital region are sometimes associated with a certain weakness of grasp and feebleness of wrist flexion. The facts that only this aponeurotic expansion separates the median basilic vein from the brachial artery, and that in persons of poor muscular development it is often so thin as scarcely to constitute a recognizable layer, were of practical importance when phlebotomy of the median basilic was frequent. Arterio-venous aneurism from accidental puncture of the artery was then quite common.

Posteriorly the outer aponeurotic expansion of the triceps, running over the anconeus to become continuous with the deep fascia of the forearm, is of importance in its relation to the power of extension of the forearm after excision of the elbow (page 308).

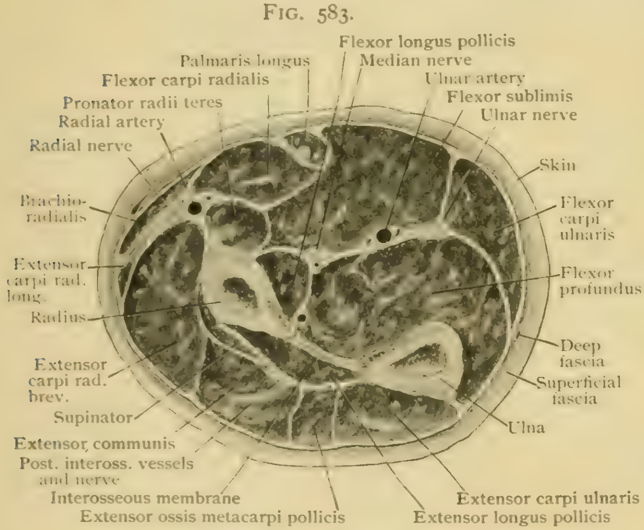
The fascia of the forearm, besides giving origin to many fibres of the subjacent muscles, as has been noted above, envelops the forearm completely, being continu-

ous at the wrist with the anterior and posterior annular ligaments. The septa which run in from it to be attached to the sides of the ulna and radius divide the forearm, with the aid of the interosseous membrane, into two musculo-aponeurotic spaces, an antero-external and a posterior (Fig. 583). The former contains numerous muscles and the main vessels and nerves, the latter is almost entirely muscular.

The interpenetration of these main septa and of the intermuscular fascia by nervo-vascular structures renders them of slight importance in limiting the spread of infectious disease or of collections of blood or pus. But in the not infrequent cases of incised wounds severing the muscles and tendons of this region it may systematize the search for and reunion of the divided structures if the somewhat artificial topography, as described by Tillaux, is borne in mind. The antero-external compartment is thus regarded as including four spaces. 1. That between the skin and the first muscular layer,—the palmaris, flexor carpi ulnaris, pronator radii teres, etc.,—and containing the internal cutaneous and musculo-cutaneous nerves, the perforating branches of the radial and ulnar nerves, the superficial veins, and sometimes the ulnar artery when there is a high bifurcation of the brachial. 2. That between the first muscular layer and the flexor sublimis, with the brachio-radialis and short supinator externally. This contains the radial nerve, artery, and veins. 3. That between the flexor sublimis and the flexor profundus and flexor longus pollicis. This contains the median nerve and the ulnar nerve and vessels. 4. That between the last-named muscles and the interosseous membrane, containing the anterior interosseous vessels and the interosseous nerve.

In the posterior compartment are to be found, in addition to the extensors and the anconeus, only the posterior interosseous vessels and nerve (Fig. 583).

Fig. 583.



Section across middle of right forearm.

Fractures of the neck of the radius (between the head and the tuberosity) are very rare, as it is covered and protected from direct violence by the long and short supinators and the long and short radial extensors. Angular displacement forward is thought to be caused by the action of the biceps on the upper end of the lower fragment. The upper fragment is rotated outward by the supinator brevis. Fracture of the radius below its tubercle and above the insertion of the pronator radii teres (a little above the middle of the outer side of the bone) is followed by supination and flexion of the upper fragment by the biceps and supinator brevis. The lower fragment is pronated and drawn towards the ulna by the pronators.

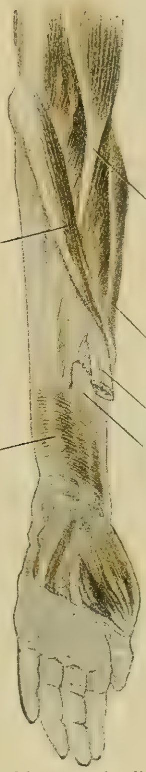
It is well to treat cases of this fracture with the forearm in moderate supination, so as to approximate the fragments and preserve the axis of the bone and the future usefulness of the supinators.

In fracture of the radius below the insertion of the pronator radii teres the upper fragment is flexed by the biceps, so that its lower end can sometimes be seen and felt on the front of the forearm just above the middle, and is sometimes pronated by the pronator radii teres; the lower fragment is drawn towards the ulna by the pronator quadratus, aided by the action of the brachio-radialis on the styloid process (Fig. 584).

In the usual position in which such fractures are treated, the flexion of the elbow

and the mid-position between pronation and supination sufficiently relax the biceps and the pronator radii teres. The weight of the hand in adduction overcomes the pull of the brachio-radialis and pronator quadratus.

FIG. 584.



Dissection of fracture of radius between the two pronator muscles.

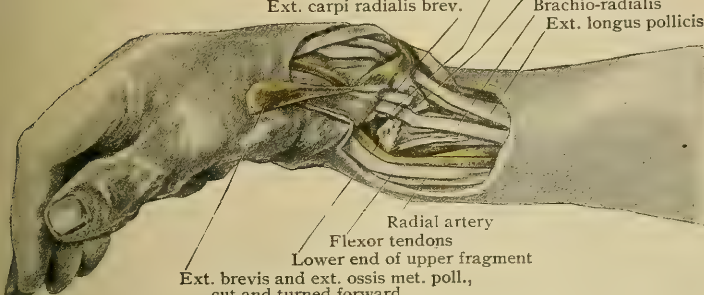
FIG. 585.

Dissection of fracture of olecranon process of left ulna; joint opened from behind.

Fracture of both bones, from either direct or indirect violence, usually takes place below the middle of the forearm, as there the muscular masses which protect the upper half of the radius from direct violence have largely been replaced by tendons, the ulna is slender and weak, and the opposing forces represented by the biceps and brachialis anticus above and the weight or force applied through the hand expend themselves. Thus Malgaigne (quoted by Agnew) reports a case in which both bones were broken by muscular action alone while the patient was carrying weight in the form of a shovelful of dirt. When the resulting deformity is due chiefly to the contraction of muscles, it is apt to consist in flexion of both upper fragments by the biceps and brachialis anticus, supination of the upper fragment of the radius by the biceps and supinator brevis, and approximation of the two lower fragments by the pronator quadratus. Much overlapping and shortening are usually prevented by the untorn fibres of the interosseous membrane.

During the period of repair the mid-position—between pronation and supination —preserves the parallelism of the two bones, maintains the interosseous space at almost its greatest width, relaxes (in conjunction with the flexion of the elbow) the muscles involved so far as is possible, and by the weight of the hand dropping to the ulnar side overcomes the resistance of others, especially of the brachio-radialis.

FIG. 586.



Dissection of Colles's fracture of radius, showing relation of tendons and radial artery.

The large proportion of the return current of blood that is carried by the superficial veins of the forearm makes it especially important that the splints used should be so broad that the bandage does not unduly com-

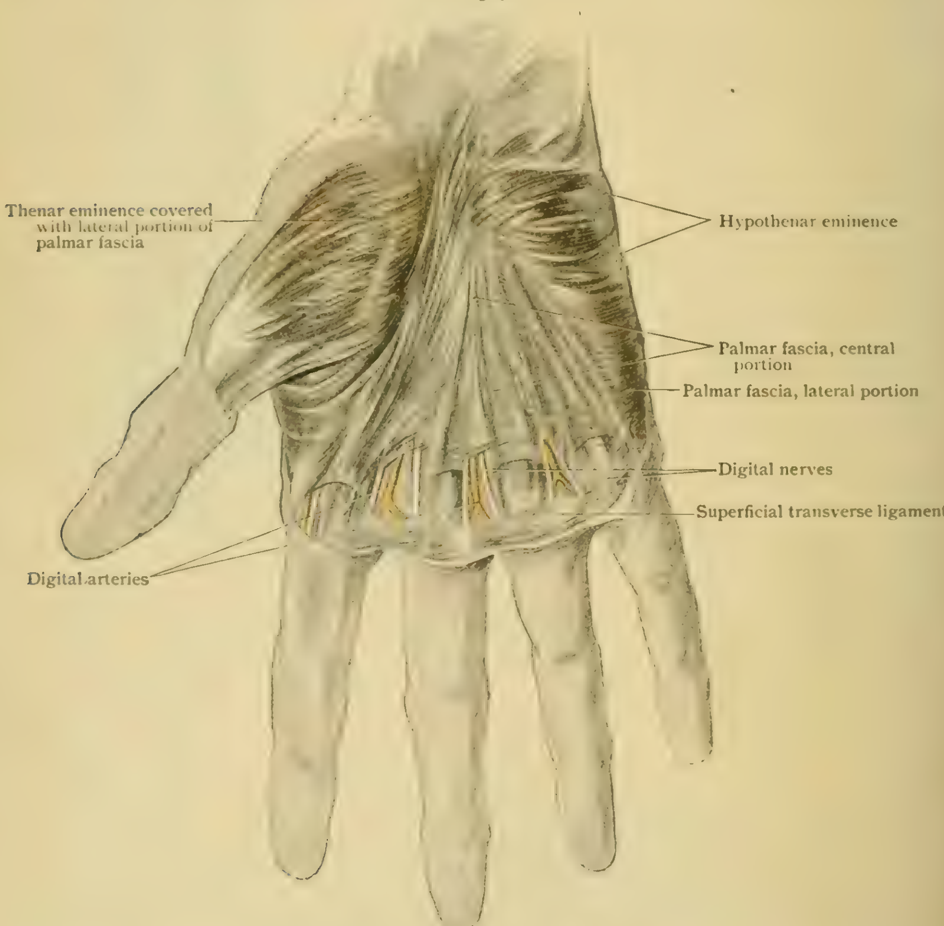
press the soft tissues; while the ease with which both veins and arteries may be obstructed at the bend of the elbow should lead to careful avoidance of pressure in that region from the upper end of the palmar splint.

The preservation of the interosseous space is favored by the omission of the primary roller bandage and by the avoidance of direct pressure upon the soft parts by the bandage used to retain the splints.

THE MUSCLES OF THE HAND.

The Deep Fascia of the Hand.—The deep fascia of the palmar surface of the hand is usually regarded as being represented by the *palmar aponeurosis*, a firm sheet of connective tissue which occupies the palm of the hand and lies imme-

FIG. 587.



Superficial dissection of hand, showing palmar fascia.

diately beneath the skin. This structure represents, however, the superficial layer of a thick aponeurosis which occurs in the lower vertebrates, receiving the insertion of the antibrachial flexors and giving origin to the digital flexors. From the proximal portion of this aponeurosis there is formed, however, the anterior annular ligament, and this may be considered as a portion of the palmar aponeurosis.

The latter (Fig. 587), often called the *palmar fascia*, is a fan-shaped sheet whose apex is directed proximally, receiving the insertion of the palmaris longus and being to a certain extent continuous with the anterior annular ligament. It reaches

its greatest breadth over the distal portions of the metacarpals, and is continued onward as four more or less distinct bands, which are inserted into the integument at the bases of the second, third, fourth, and fifth fingers. A little below the lower edge of the aponeurosis transverse bands of fascia (**fasciculi transversi**) stretch across between the same fingers, lying immediately beneath the skin and being connected to a greater or less extent with one another. These bands constitute the *superficial transverse metacarpal ligament* beneath the webs of the fingers.

The *anterior annular ligament* (**ligamentum carpi transversum**) (Fig. 578) is a strong band which stretches across from the trapezium and scaphoid bones of the carpus on the radial side to the pisiform and unciform bones on the ulnar side, forming a bridge across the groove on the anterior surface of the carpus which transmits the tendons of the long flexors and of the flexor carpi radialis and the median nerve. The canal so formed is divided by a partition into a small radial compartment through which the flexor carpi radialis passes, and a large ulnar one which gives passage to the other structures mentioned. The tendons are enclosed within synovial sacs which extend downward to about the middle of the palm and upward to a short distance above the upper edge of the ligament. The sac which surrounds the flexor longus pollicis is usually separate from that which surrounds the remaining tendons of the ulnar compartment ; occasionally the portion surrounding the tendons of the index-finger is also separate.

Towards either side of the palmar surface of the hand the palmar fascia forms a thin covering for *thenar* and *hypothenar eminences* formed by the superficial muscles of the thumb and the little finger respectively. Upon the dorsal surface the fascia is thin, and is continued downward from the lower border of the posterior annular ligament over the extensor tendons to the fingers, where it unites with the aponeuroses of the tendons.

(*a*) THE PRE-AXIAL MUSCLES.

The pre-axial muscles of the hand are to be regarded, from the comparative stand-point, as being arranged in five layers. Although these layers become confused to a certain extent in the human hand, it will, nevertheless, aid in the proper understanding of their relations to group them according to the primary layers from which they are derived.

(*aa*) The Muscles of the First Layer.

1. Palmaris brevis.
2. Abductor pollicis.
3. Opponens pollicis.
4. Flexor brevis pollicis.
5. Abductor minimi digiti.
6. Opponens minimi digiti.
7. Flexor brevis minimi digiti.

The most superficial layer of the palmar muscles in the lower vertebrates takes its origin from the palmar aponeurosis. The greater portion of the layer, as has already been pointed out, becomes converted in the mammalia into the palmar portions of the tendons of the flexor sublimis digitorum, and it is only towards either margin of the hand that it persists as muscles, which show indications of their primary relations in their origin from the palmar aponeurosis or the anterior annular ligament.

1. Palmaris Brevis (Fig. 576).

Attachments.—The palmaris brevis is a thin quadrangular sheet which lies immediately beneath the skin of the hypothenar eminence. It *arises* from the proximal portion of the ulnar border of the palmar aponeurosis and is *inserted* into the skin of the ulnar border of the hand.

Nerve-Supply.—By the superficial division of the ulnar nerve from the first thoracic nerve.

Action.—To wrinkle the skin upon the ulnar border of the hand, deepening the hollow of the hand.

Variations.—The muscle may be greatly reduced in size and is occasionally wanting.

2. Abductor Pollicis (Fig. 577).

Attachments.—The abductor of the thumb (**m. abductor pollicis brevis**) is the most superficial muscle of the thenar eminence. It *arises* from the anterior annular ligament and from the scaphoid bone or the trapezium and passes distally to be *inserted* along with the flexor brevis pollicis into the radial side of the base of the first phalanx of the thumb and into the sheath of the tendon of the extensor longus pollicis.

Nerve-Supply.—By the median nerve from the sixth and seventh cervical nerves.

Action.—To flex and abduct the thumb.

Variations.—The portion of the muscle arising from the carpus is sometimes separate from that taking origin from the transverse carpal ligament. Slips are occasionally sent to the abductor from the extensores carpi radiales, the extensor ossis metacarpi pollicis, the opponens pollicis, and the flexor brevis pollicis.

3. Opponens Pollicis (Figs. 578, 588).

Attachments.—The opponens pollicis is almost completely covered by the abductor pollicis. It *arises* from the anterior annular ligament and from the trapezium, and is *inserted* into the whole length of the radial border of the first metacarpal.

Nerve-Supply.—By the median nerve from the sixth and seventh cervical nerves.

Action.—To flex and adduct the thumb, opposing it to the other fingers.

4. Flexor Brevis Pollicis (Figs. 578, 588).

Attachments.—The flexor brevis pollicis lies along the lower (ulnar) border of the opponens pollicis. It *arises* from the lower border of the anterior annular ligament and is *inserted*, along with the abductor pollicis, into the radial side of the base of the first phalanx of the thumb.

The muscle above described is usually regarded by English anatomists as representing the outer or radial head of the flexor brevis, a second inner or ulnar head being included as part of that muscle. Concerning the inner head three views are held: (*a*) no inner head is recognized, the small slip arising from the ulnar side of the base of the first metacarpal bone and passing downward to be inserted with the adductor pollicis into the base of the first phalanx, which by many English anatomists is regarded as a small inner head of the flexor brevis, being described as an additional (first) palmar interosseus (page 612); (*b*) the small slip just noted is the inner or ulnar head of the flexor brevis; (*c*) the small slip and all the fibres described as forming the adductor obliquus (page 610) are regarded as the inner head of the flexor brevis. The first view, adopted by German anatomists, is here followed.

Nerve-Supply.—By the median nerve from the sixth and seventh cervical nerves.

Action.—To flex the first phalanx of the thumb.

Variations.—The muscle is sometimes intimately connected with the abductor pollicis and opponens pollicis.

5. Abductor Minimi Digiti (Fig. 577).

Attachments.—The abductor of the little finger (**m. abductor digiti quinti**) occupies the ulnar border of the hand. It *arises* from the anterior annular ligament and from the pisiform bone and is *inserted* into the ulnar side of the base of the first phalanx of the little finger.

Nerve-Supply.—By the deep division of the ulnar nerve from the eighth cervical and first thoracic nerves.

Action.—To abduct the fifth finger.

6. Opponens Minimi Digiti (Fig. 578).

Attachments.—This muscle (**m. opponens digiti quinti**) is almost completely covered by the abductor and short flexor of the little finger. It *arises* from the anterior annular ligament and the uncinate process of the unciform bone and is *inserted* into the whole of the ulnar border of the fifth metacarpal bone.

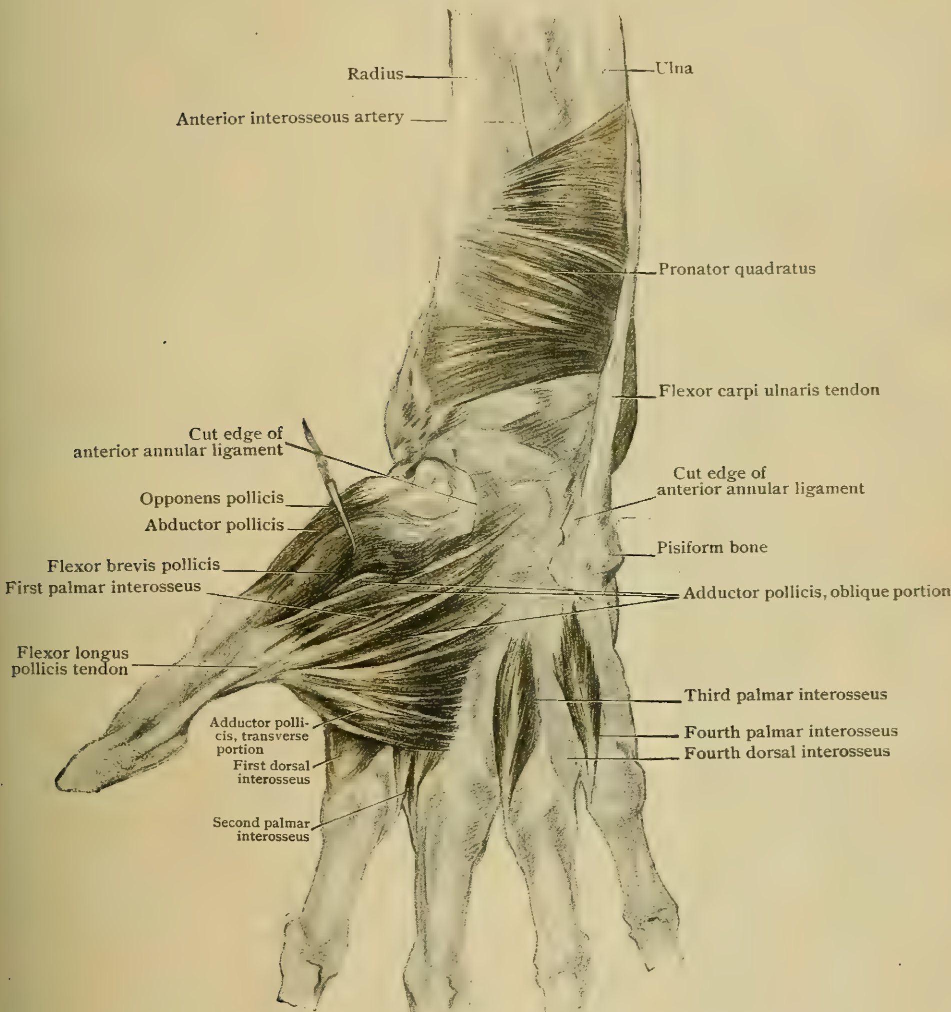
Nerve-Supply.—By the deep division of the ulnar nerve from the eighth cervical and first thoracic nerves.

Action.—To flex and at the same time adduct the fifth metacarpal.

7. Flexor Brevis Minimi Digiti (Figs. 577, 578).

Attachments.—The short flexor of the little finger (**m. flexor brevis digiti quinti**) lies along the lateral (radial) border of the abductor minimi digiti. It *arises*

Fig. 588.



Deep dissection of wrist and hand, showing pronator quadratus and short muscles of thumb.

from the anterior annular ligament and the uncinate process of the uncinate bone and is *inserted* into the ulnar side of the base of the first phalanx of the little finger.

Nerve-Supply.—By the deep division of the ulnar nerve from the eighth cervical and first thoracic nerves.

Action.—To flex and slightly abduct the first phalanx of the little finger.

Variations.—The flexor brevis and opponens minimi digiti are often united by muscle-bundles and may even be completely fused.

(*bb*) The Muscles of the Second Layer.

In the lower vertebrates the second layer also arises from the palmar aponeurosis, but from its deeper layers. These, as has been stated (page 597), differentiate into the palmar portions of the tendons of the flexor profundus digitorum, and in the mammalia the muscles retain their primary origin and arise from those tendons forming the lumbrical muscles.

1. Lumbricales (Fig. 578).

Attachments.—The lumbricals are four slender, band-like muscles, situated in the palm of the hand. Counting from the radial side of the hand, the *first* and *second* lumbricals *arise* from the radial side of the flexor profundus tendons to the index and middle fingers respectively, while the *third* one *arises* from the adjacent sides of the tendons to the middle and ring fingers, and the *fourth* from those of the tendons to the ring and little fingers. The muscles pass distally into slender tendons which are continued to the radial side of the first phalanges of the second, third, fourth, and fifth fingers, and are *inserted* into the membranous expansions of the tendons of the extensor communis digitorum to those fingers.

Nerve-Supply.—The first and second lumbricals are supplied by the median nerve from the sixth and seventh cervical nerves; the third and fourth by the deep division of the ulnar nerve from the eighth cervical and first thoracic nerves.

Action.—To flex the first phalanges of the second, third, fourth, and fifth fingers. At the same time, by their traction upon the extensor tendons, they will tend to keep the second and third phalanges extended.

Variations.—Variations in the arrangement of the lumbricals, and especially of the third and fourth, are not uncommon. The tendon of each of these muscles may bifurcate and be inserted into the adjacent sides of the third and fourth or fourth and fifth fingers, and more rarely the sole insertions may be into the ulnar sides of the first phalanges of the middle and ring fingers. The third lumbrical is frequently supplied wholly or in part from the median nerve.

(*cc*) The Muscle of the Third Layer.

In the lower vertebrates the third layer consists of muscles which arise from the carpal and metacarpal bones and pass to each of the digits. In the mammalia they become greatly reduced in number, frequently persisting, however, in connection with the thumb, index, and little fingers, but in man they are represented only by an adductor pollicis.

1. Adductor Pollicis (Figs. 578, 588).

Attachments.—The adductor pollicis is a flat triangular muscle which rests upon the metacarpal bones and the interosseous muscles. It may be regarded as consisting of two portions. The *portio obliqua* (often described as a distinct muscle, the *adductor obliquus pollicis*) *arises* from the trapezium, trapezoid, and os magnum and from the bases of the second and third metacarpals. Its fibres are directed distally and radially, and are *inserted* by a tendon, in which a sesamoid bone is usually developed, into the ulnar side of the base of the first phalanx of the thumb. It also sends off a slip which passes beneath the tendon of the flexor longus pollicis to be inserted into the radial side of the base of the first phalanx of the thumb along with the flexor brevis pollicis.

The *portio transversa* (often described as the *adductor transversus pollicis*) *arises* from the lower two-thirds of the volar surface of the third metacarpal, and its fibres pass almost directly radially to be *inserted* into the ulnar side of the base of the first phalanx of the thumb.

Nerve-Supply.—By the deep division of the ulnar nerve from the eighth cervical and first thoracic nerves.

Action.—To adduct the thumb.

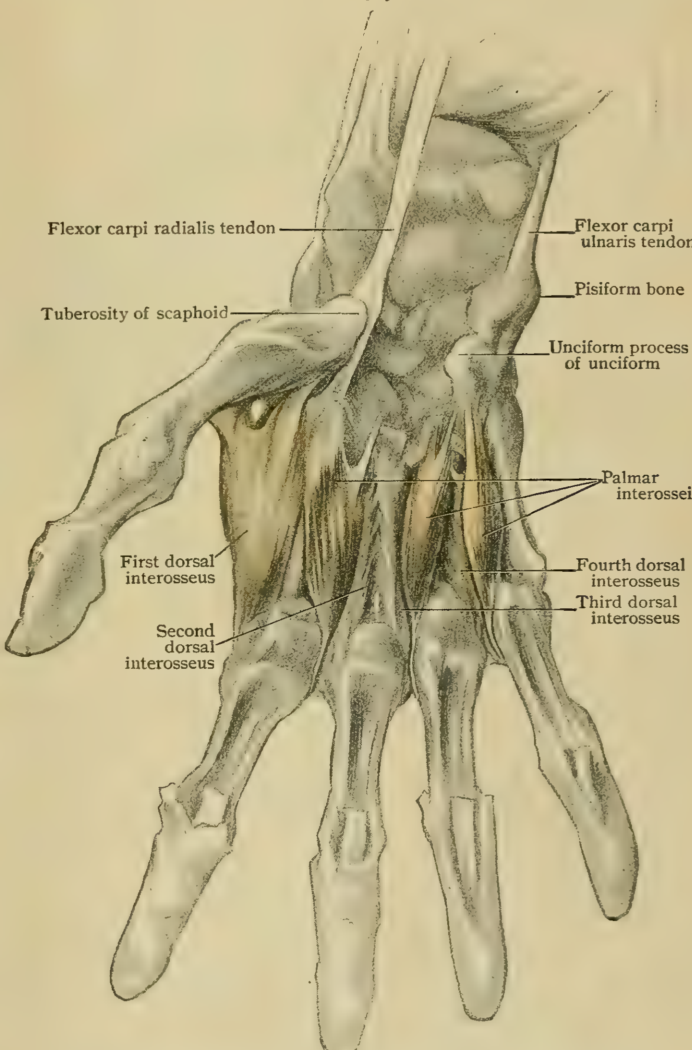
Relations.—The adductor pollicis is covered by the tendons of the flexor profundus digitorum for the second and third fingers and by the first and second lumbricals. It conceals the interosseous muscles of the two radial intermetacarpal intervals and also the radial artery and the arteria princeps pollicis. The deep palmar arch passes between the two portions of the muscle, near their origins.

(*dd*) THE MUSCLES OF THE FOURTH AND FIFTH LAYERS.

1. Interossei volares. 2. Interossei dorsales.

In the lower vertebrates the musculature of the fourth palmar layer consists of a pair of muscles for each digit, arising from the carpal and metacarpal bones and inserting into either side of the base of the first phalanx. The fifth layer lies dorsal to these, and consists of four muscular bands, which extend slightly obliquely across the four intermetacarpal spaces.

FIG. 589.



Deep dissection of hand, showing interosseous muscles as seen in palm.

In the mammalia a shifting of the insertion of one of the muscles of the pairs belonging to the first and fifth digits takes place, so that they are attached to the radial and ulnar sides respectively of the adjacent second and fourth digits, uniting with the corresponding members of the pairs belonging to those digits. With the compound muscles so formed the first and fourth intermetacarpal muscles unite to form the first and fourth dorsal interossei, these two muscles being composed, accordingly, by the fusion of three primary muscles.

The second and third intermetacarpal muscles unite with the radial and ulnar members respectively of the pair belonging to the third digit, and form with these the second and third dorsal interossei.

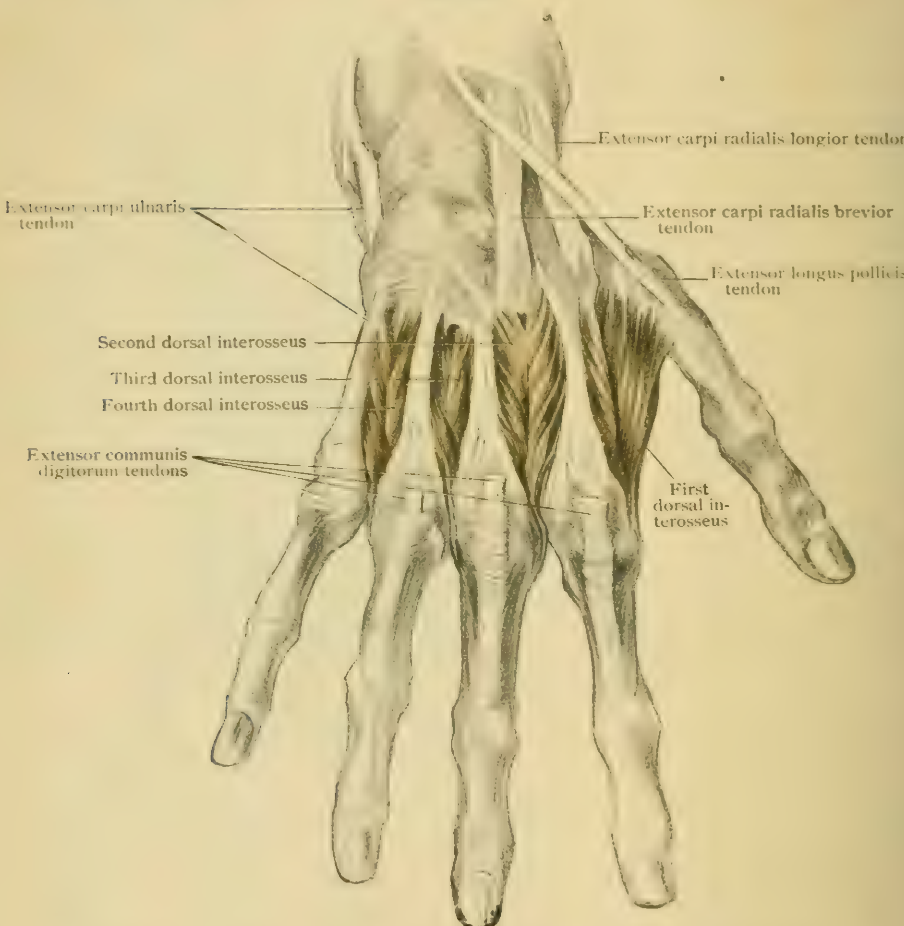
The remaining members of the pairs belonging to the first, second, fourth, and fifth digits persist as independent muscles, forming what are termed the volar interossei, whose arrangement is consequently complementary to that of the dorsal interossei.

The intermetacarpal muscles occupy the most dorsal position of all the palmar muscles, and it is probably owing to their participation in the formation of the dorsal interossei that these possess an almost dorsal position in the hand. They are clearly, however, of palmar origin and are supplied by pre-axial nerves.

1. Interossei Volares (Fig. 589).

Attachments.—The volar or *palmar interossei* are four slender muscles situated in the intervals between the metacarpal bones and resting upon the interossei dorsales. The *first* and *second* muscles, counting from the radial side, *arise* from the ulnar side of the bases of the first and second metacarpals, and are *inserted* into the ulnar side of the base of the first phalanx and, in the case of the second muscle, also into the membranous expansion of the long extensor tendon of the corresponding digit. The *third* and *fourth* muscles *arise* from the radial side of the fourth and fifth metacarpals, and are *inserted* similarly to the second muscle, but into the radial sides of the fourth and fifth digits.

Fig. 590.



Dissection of back of hand, showing dorsal interossei and insertion of extensor tendons.

Only three palmar interossei are usually described by English anatomists, the muscle included in the series by the German school as the first interosseus (*m. interosseus primus volaris*) being regarded as the small ulnar head of the flexor brevis pollicis (page 608). The inclusion of this muscle in the series of palmar interossei is warranted by its morphological relations.

Nerve-Supply.—By the deep division of the ulnar nerve from the eighth cervical and first thoracic nerves.

Action.—To draw the first, second, fourth, and fifth digits towards the middle finger and to flex the first phalanx of the same digits.

Variations.—The first volar interosseus is the most slender of the series and is covered by the oblique portion of the adductor pollicis, with which it may be practically incorporated. Occasionally it is so reduced in size as to appear to be wanting.

2. Interossei Dorsales (Fig. 590).

Attachments.—The dorsal interossei are also four in number and lie in the intervals between the metacarpal bones, dorsal to the volar interossei. Each is a bipinnate muscle *arising* from the adjacent surfaces of the metacarpals which bound the interspace in which the muscle lies. The *first* and *second* muscles, counting from the radial side, are *inserted* into the radial side of the base of the first phalanx and into the membranous expansion of the extensor tendons of the second and third fingers, while the *third* and *fourth* are *inserted* similarly into the ulnar sides of the third and fourth fingers.

Nerve-Supply.—By the deep division of the ulnar nerve from the eighth cervical and first thoracic nerves.

Action.—The first and fourth muscles draw the second and fourth fingers away from the third, while the second and third draw the third finger radially or ulnarly, as the case may be. All the muscles flex the first phalanx of the digits to which they are attached.

Variations.—Occasionally the second dorsal interosseus is inserted into the base of the first phalanx of the index-finger, upon its ulnar side.

(*b*) THE POST-AXIAL MUSCLE.

Normally no post-axial muscles exist in the human hand. Occasionally, however, an *extensor brevis digitorum manus* is more or less perfectly developed. It arises from the dorsum of the carpus, or sometimes from the lower end of the radius and ulna, and passes distally into a varying number of tendons. Most frequently the muscle is small and gives rise to but a single tendon, which joins with the tendon of the extensor digitorum communis of either the second or third digit. Sometimes two tendons occur, passing to the second and third digits, and more rarely three have been observed, passing to the second, third, and fourth fingers. In a single case a fourth tendon was observed which terminated upon the dorsal surface of the fifth metacarpal.

PRACTICAL CONSIDERATIONS.

The Wrist and Hand.—The skin of the wrist and of the back of the hand is thin and freely movable and contains numerous hair-follicles and sebaceous glands. These structures are absent in the palm and on the palmar and lateral surfaces of the fingers, as well as on the dorsal surface of the terminal phalanges. Sudoriparous glands are, on the contrary, relatively more numerous in the palms of the hands than on any other part of the body surface.

These anatomical conditions and the existence of the subungual and periungual spaces and irregularities render the sterilization of the hands for surgical purposes very difficult.

The absence of hair-follicles and of sebaceous glands explains the freedom of the palm from the superficial furuncular infections that are so common on the dorsum.

In the palm the subcutaneous connective tissue, like that in the plantar region and in the scalp between the skin and aponeurosis, is very dense. This similarity has already been alluded to (page 491) in relation to the absence of hair-follicles in the two former regions and the frequency of baldness in the latter.

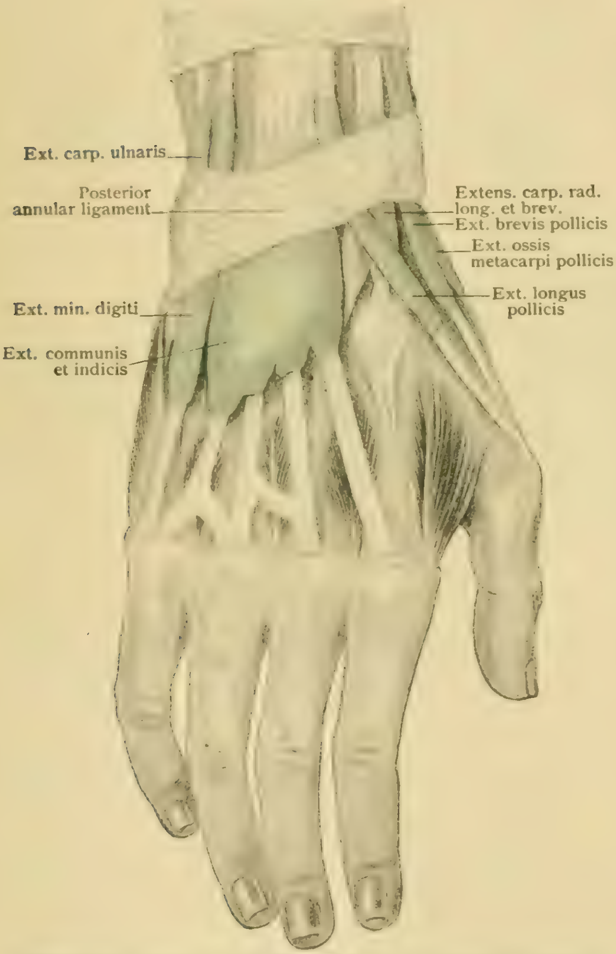
On the dorsal surface the subcutaneous tissue is loose. As a result, in whitlow, in palmar abscess, in hemorrhagic extravasation, in œdema or cellulitis, the swelling is apt to be much more marked on the dorsum and may be misleading as to the real seat of the trouble. Abscesses immediately beneath the palmar fascia will sometimes point in a metacarpal space on the dorsum.

The thickness and close adhesion of the skin to the dense fascia beneath, while admirably protecting the vessels and nerves of the palm and enabling it to withstand pressure and friction, greatly increase the pain in cutaneous or subcutaneous infections. On account of this same adhesion, superficial wounds of the palm do not gape, and heal readily if non-infected and kept at rest.

"It must be noted that the front of the hand, and especially the palm, is singularly free from surface veins. Indeed, the great bulk of the blood from the hand is returned by the superficial veins on the dorsum of the fingers and hand" (Treves).

The annular ligaments at the wrist are of importance in their relation to the tendons and their sheaths. The tendon-sheaths (Fig. 591) which pass through the six compartments in or under the posterior ligament behave as follows. 1. That for the short extensors and the extensor of the metacarpal bone of the thumb runs from the joint between the first metacarpal and the trapezium to a point almost an inch above the styloid process of the radius. 2. That for the long and short radial extensors of the carpus runs from the insertions of those muscles to a point a half inch above the ligament. 3. That for the extensor longus pollicis runs from the insertion to the upper border of the ligament. 4. That for the extensor indicis extends from the upper border of the metacarpus, and that for the extensor communis from the middle of the metacarpus, both to the upper border of the ligament. 5. That for the extensor minimi digiti runs from the middle of the metacarpus; and 6, that for the ulnar extensor of the carpus from the insertion, both to the upper border of the ligament.

Fig. 591.



Dissection of dorsum of hand, showing artificially distended sheaths of extensor tendons.

Infective disease of the dorsum of the wrist and hand is rare as compared with the palmar surface. The dense connective-tissue fibres of the palm run vertically downward to the palmar fascia and tendon-sheaths, and thus convey infection directly to the deeper parts. This layer is often described as the superficial palmar fascia. The subcutaneous connective-tissue fibres on the dorsum run horizontally, and infective inflammation is therefore more likely to remain superficial (Warren). If, however, it does penetrate and gains access to the tendon-sheaths, the natural anatomical limitations are those indicated above.

Teno-synovitis from strain, from gout, or from rheumatism is especially frequent in these sheaths, on account of their exposure to wet and cold, and also because the muscles connected with them are relatively weak and are less often used than those on the palmar surface of the forearm. They are thus more liable to strain from unaccustomed exertion.

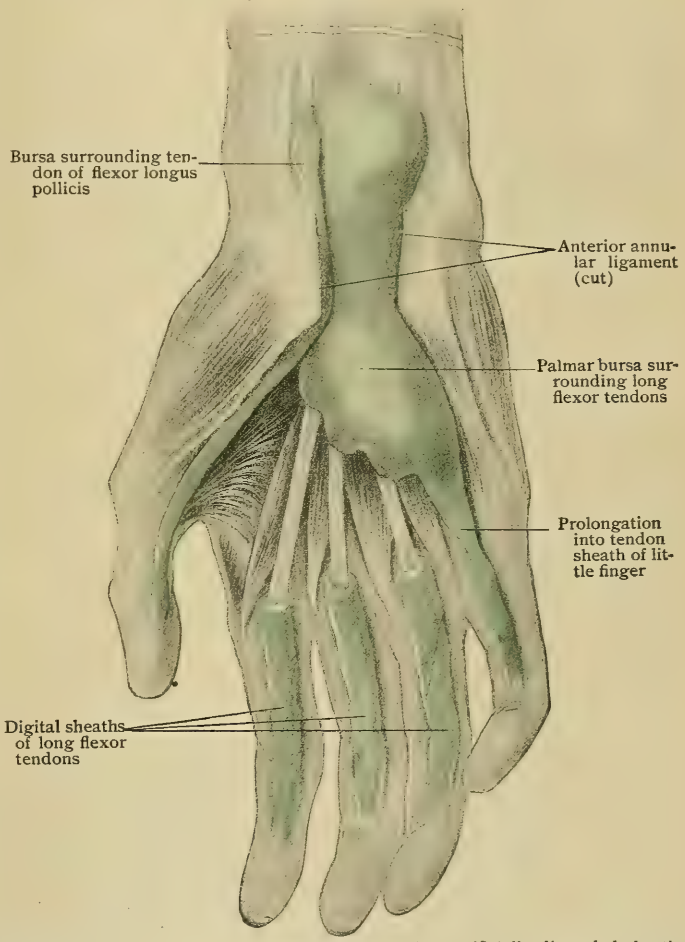
Ganglion of the simple (non-tuberculous) variety is also frequent here, probably for the same reasons.

One of the most common and most serious of the sequelæ of fracture of the lower end of the radius is stiffness of the wrist and fingers from adhesions of these extensor tendons and their sheaths to the bone, to each other, and to the surrounding structures.

It is important to remember, as Treves has pointed out, that "the tendons do not lie free within the sac, but are bound to it by folds of synovial membrane in much the same way as the bowel is bound to the abdominal parietes by its mesentery (Fig. 492). These folds may be ruptured in severe sprains, when the nutrient vessels for the tendon, which are contained in them, may be torn. Rupture is followed by effusion into the sac. These folds are almost absent within the digital sheaths, the slight ligamenta longa and brevia, near the insertion of the tendons, being the sole representatives. Synovial sacs are lined by endothelium, and have extremely free communication with the lymphatic vessels of the part. Hence the free absorption of infective matter from such cavities."

The arrangement of the synovial sheaths beneath the anterior annular ligament is of great practical importance (Fig. 592). There are two sacs, one for the tendons of the superficial and the deep flexors; one for the long flexor of the thumb. They extend upward to about two finger-breadths above the annular ligament. Downward, that for the thumb extends to the insertion of the tendon in the terminal phalanx; the diverticula for the index, middle, and ring fingers end about the middle of the metacarpal bones; that for the little finger accompanies the tendon of the deep flexor to its insertion in the last phalanx. The synovial sheaths for the digital portions of the flexors for the index, middle, and ring fingers extend upward only to about the necks of the corresponding metacarpal bones. They are thus separated by an interval of from half an inch to an inch from the synovial sac, extending up under the annular ligament to the forearm (Fig. 592).

FIG. 592.



Dissection of palmar surface of right hand, showing artificially distended sheaths of flexor tendons.

It results from this that infections (felons, wounds, etc.) of the thumb or little finger are especially apt to extend upward above the wrist and involve the forearm.

Compound ganglion (tuberculous teno-synovitis) frequently affects the common synovial sac of the flexor tendons and not infrequently that of the longus pollicis.

The two sacs occasionally communicate with each other. On account of the density of the annular ligament, the distention has a central constriction and expansions in the palm and above the wrist,—"hour-glass shape." These tendons also are often involved in fractures of the lower end of the radius, although, on account of the fact that the extensors are in closer relation to that bone than is the deep flexor, and that the other flexors—excepting the longus pollicis—are still farther separated from it, limitation of their motion is neither so frequent nor so marked.

In the palm of the hand the thenar and hypothenar eminences are covered in by their fasciæ, which separate them from the central space of the palm through which the flexor tendons run, and over which is spread the fan-shaped, deep palmar fascia, beginning at the tendon of the palmaris longus above, and spreading out to be divided below into the slips for the fingers (Fig. 587). Transverse fibres unite and strengthen these slips, which send fibres also to the sheaths of the flexor tendons and to the skin.

It may be noted here that *progressive muscular atrophy* usually begins in the hand muscles, affecting first those of the thenar, then those of the hypothenar eminence, and next the interossei. When the latter are greatly wasted the hand assumes the appearance of a bird's claw,—the *main en griffe* (Duchenne).

Dupuytren's contraction affects chiefly the digital prolongations of the palmar fascia, although it extends secondarily to the bundles of fibres uniting the skin and the aponeurosis. It begins usually as a dense thickening of the fascia near the line of the metacarpo-phalangeal articulation. It extends in both directions, the concomitant shortening slowly drawing down first the distal and then the intermediate phalanx. The skin becomes closely adherent to the contracted fascia. The condition is seen oftenest in hands subjected to frequent slight traumatism, as in laborers, or in those of gouty or rheumatic persons past middle age.

Beneath the flexor tendons, and above the interossei, the metacarpal bones, and the radial arch, lies another layer of fascia (interosseous) which resists but feebly the passage of pus towards the dorsum of the hand. It is connected with the thenar and hypothenar fasciæ.

Several varieties of *palmar abscess* have been described (Tillaux) in accordance with the original site of the infection, the spread of which will be determined by the above-mentioned anatomical considerations. (*a*) Infection just beneath the thick epidermis causes a superficial pustule or abscess (subepidermic) which, if promptly and freely opened, gives rise to no difficulty. (*b*) Infection beneath the skin (subdermic) is attended by more pain, and, if neglected, may penetrate the aponeurosis; but it is separated by that structure from the synovial sheaths and cavities; it may be widely opened with no reference to the latter or to vessels; it is accompanied by little or no swelling on the dorsum; it has no tendency to extend up to the wrist; movements of the fingers are not very painful. (*c*) Subdermic infection beginning in the spaces just above the interdigital clefts (*i.e.*, between the digital slips of the palmar fascia) may extend by continuity of connective tissue very rapidly to the dorsum of the hand, which may then appear to be the chief seat of the infection; the symptoms are relatively mild, as the toxic exudate is not under great pressure. (*d*) Subaponeurotic infection—true palmar abscess—is excessively painful, extends rapidly to the dorsum by perforating the interosseous fascia, and often to the front of the wrist and forearm by following up the flexor tendons; movements of the fingers are painful; the dorso-palmar diameter of the hand is vastly increased; the constitutional symptoms are often marked.

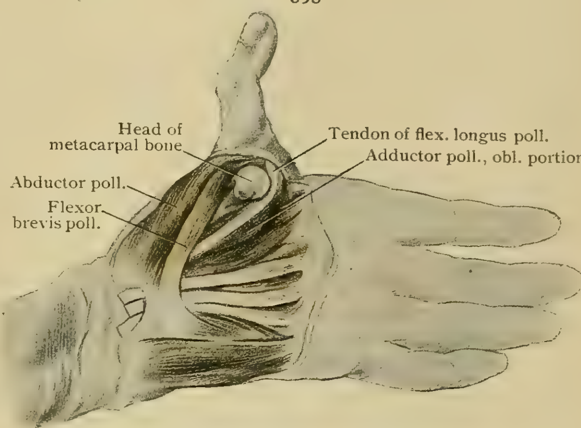
Such abscess may also point just above the interdigital webs or near the ulnar or radial borders of the hand. Early incision is imperative and, if made over the line of a metacarpal bone and limited in an upward direction by a transverse line corresponding to that of the web of the fully extended thumb (to avoid the digital vessels and palmar arches), may be made freely. Above the wrist the region of safety is just to the ulnar side of the palmaris longus.

On the fingers the skin resembles in its characteristics that of the hand. On the palmar surface of the first and second phalanges the skin and the subcutaneous fat are connected with the dense fibrous sheath of the flexor tendons by vertical connective-tissue fibres, and at the level of the joints—where the sheaths are lax and thinner—

by vessels which penetrate the sheath to supply the tendons. Over the last phalanx the fibro-fatty subcutaneous layer—the "pulp" of the finger—lies directly upon the periosteum.

Infection of the dorsum of a finger often originates near or about the root of a nail (onychia) and may involve the matrix of the latter. It is not under much pressure, and is therefore not usually serious, although through the veins and lymphatics it may exceptionally extend rapidly up the arm.

FIG. 593.



Dissection of metacarpo-phalangeal dislocation of thumb.

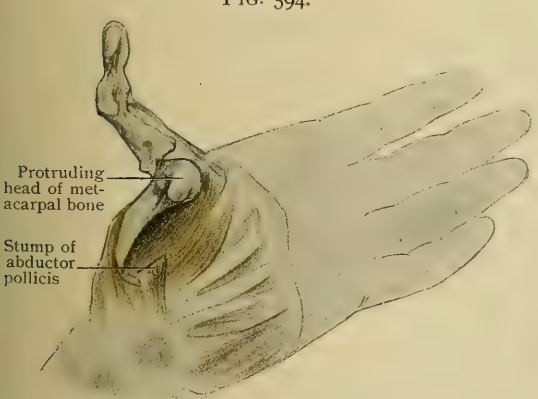
Infection of the palmar surface of a finger (panaritium, paronychia, whitlow, felon) is of two chief varieties: (*a*) *subcutaneous*, in which the symptoms are at first limited to the seat of infection and are superficial, although, as it is a true cellulitis, they may extend to the dorsum or towards the palm; and (*b*) *thecal*, with more severe pain, greater limitation of flexion, and more rapid extension upward.

If the felon involves the distal portion of the finger, the close relation of the "pulp" and the periosteum of the last phalanx makes necrosis of that bone frequent, although its upper part usually escapes because (*a*) it is an epiphysis; (*b*) the insertion of the tendon of the deep flexor probably keeps up its blood-supply (Treves).

The absence of the tendon-sheath over the body and tip of the last phalanx prevents the conversion of the subcutaneous into the thecal variety, unless the infection extends upward as far as the base of the phalanx.

Elsewhere the thecal variety often results from extension from a subcutaneous focus by the vertical connective-tissue fibres and the vessels already mentioned. The interphalangeal joints are often affected because it is opposite them that (*a*) the tendon-sheaths are thinnest and (*b*) the vessels enter. In infection of the tendon-sheaths of the index, middle, and ring fingers the upward extension is arrested, at least for a time, about opposite the necks of the metacarpal bones. If the thumb or little finger is involved, the infection is likely to spread to a higher level (page 615).

FIG. 594.



Dissection showing position of bones in dislocation of thumb.

The so-called "subcuticular" felon is a superficial pustule, while the "subperiosteal" felon may either result from extension of the foregoing varieties or may be originally an infective osteo-periostitis or osteo-myelitis.

In relation to amputation of the finger it may be noted that the insertion of the flexor sublimis tendon into the sides of the second phalanx renders amputation at the metacarpo-phalangeal joint often more satisfactory in its results than one done through the first phalanx or first interphalangeal joint.

Dislocation of the first phalanx of the thumb upon the dorsum of its metacarpal bone requires special mention on account of the difficulty of reduction. It has been

attributed (*a*) to the gripping of the neck of the metacarpal bone between the flexor brevis pollicis and the oblique portion of the adductor pollicis (these often being considered as the two heads of the flexor brevis pollicis); (*b*) to a similar entanglement of the head and neck in the slit in the capsule; (*c*) to the winding of the tendon of the flexor longus pollicis around the neck of the bone; and (*d*) to the interposition of the gleno-sesamoid plate. Of these theories the last two seem to offer the most satisfactory explanation of the difficulties met with in attempts at replacement.

The Surface Landmarks of the Upper Extremity.—The axilla (page 574) is very distinctly bounded anteriorly by the lower border of the pectoralis major, which runs in the line of the fifth rib from the sixth costal cartilage to the external bicipital ridge; posteriorly by the lower edge of the latissiums dorsi and teres major, extending to the bicipital groove. The shape of the axillary fossa varies with the position of the arm, becoming deeper when the arm is raised at a right angle to the trunk or when the great pectoral and latissimus are contracted. With the arm still farther elevated, the depth of the space decreases as traction on those muscles approximates the axillary borders and the humeral head enters and partly obliterates the cavity. With the arm close to the thorax, the third rib may be reached by the exploring finger. The concavity of the space is lessened or effaced by glandular tumors, effusions of blood, or collections of pus (page 582). In opening an axillary abscess it should be remembered that the inner or thoracic wall is the direction of safety so far as the great vessels are concerned.

In the region of the shoulder the rounded surface is produced by the thick deltoid muscle spread over the greater tuberosity of the humerus. It is fuller anteriorly than posteriorly, partly on account of the presence of the lesser tuberosity in the former position, but chiefly because the hinder portion of the muscle is thinner than the fore part and because of its close attachment to the infraspinatus fascia and muscle. The greatest width of the shoulders does not correspond to the points at which the deltoid muscles overlap the head of the humerus, but is at the level of the lower border of the anterior axillary fold,—*i.e.*, on the level of the point at which the various bundles of deltoid fibres are gathered together to pass to their insertion (Thomson). The bony points in this region have been described (pages 270, 279, 280). The anterior border of the deltoid presents a rounded eminence bounded internally above by the infraclavicular fossa (*vide infra*) and below by the closely applied outer margin of the pectoralis major. In the shallow groove between these two muscles the cephalic vein and a branch of the acromio-thoracic artery are to be found. Just external to the groove under the inner fibres of the deltoid is the coracoid process (page 255). The infraclavicular fossa is the triangular interval bounded by the outer fibres of the pectoralis major internally, the inner fibres of the deltoid externally, and the clavicle above. The surface depression known by this name may be much larger than this intermuscular interval, and may almost correspond in extent to the roof of the superficial infraclavicular triangle (page 581). It is not very marked in muscular subjects. It is effaced—owing to tension of fascia and muscles—in subcoracoid luxation of the humerus, or in fracture of the clavicle with marked displacement of the fragments. It may be converted into a rounded elevation by glandular growths extending upward from the axilla, or by the head of the humerus in intracoracoid (infraclavicular) luxation. At the bottom of this fossa, just within the coracoid process,—*i.e.*, not far from the middle of the clavicle,—the first portion of the axillary artery may be compressed against the second rib by pressure directed backward and a little inward, the patient being supine.

The posterior border of the deltoid above is tendinous, is closely attached to the infraspinatus muscle beneath it, and is scarcely discernible. Below it is thicker and presents a well-marked rounded eminence which inclines from behind forward to meet the anterior border at the middle of the outer side of the arm, where a distinct depression indicates the insertion of the deltoid (Fig. 595). This depression is a valuable practical landmark for the reasons that: (1) It corresponds to the middle of the shaft of the humerus, where the two curves of the bone unite and where the cylindrical joins the prismatic part of the shaft, which is there smallest, hardest, and least elastic (page 272), and hence is most frequently broken. (2) It indicates the region

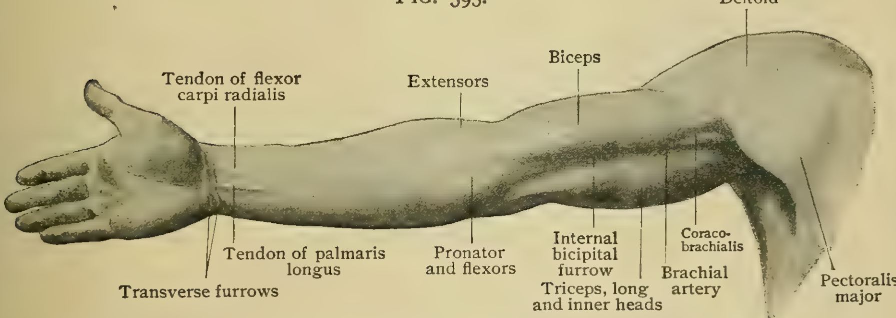
of insertion of the deltoid and coraco-brachialis, and embraces part of the origin of the brachialis anticus and internal head of the triceps, and is therefore, and on account of the intimate attachment of the periosteum (page 272), a not uncommon seat of exostoses. (3) The region is—by reason of the close relation of these muscles to the bone—a frequent seat of ununited fracture (page 273). (4) The nutrient artery enters the bone and the superior profunda artery and musculo-spiral nerve wind around its posterior surface at that level, at which also the lesser internal cutaneous nerve and the basilic vein penetrate the deep fascia, the median nerve crosses the brachial artery, and the ulnar nerve leaves it.

On the outer surface of the arm below the insertion of the deltoid can be seen the shallow furrow (Fig. 596) between the outer head of the triceps and the brachio-radialis which indicates the position of the external intermuscular septum and of the external supracondyloid ridge (page 273).

On the posterior surface of the arm the three heads of the triceps can be seen when the forearm is strongly extended (Fig. 596). The outer head makes a distinct prominence just beneath the posterior border of the deltoid; the inner head is less distinct; the long head comes into view where it descends from between the two teres muscles, and lower in the arm—where it has become tendinous—is indicated by a broad, shallow depression ending at the olecranon. The long and outer heads cover the musculo-spiral nerve and superior profunda artery from just beneath the posterior axillary fold to the point where they perforate the external septum.

On the anterior and inner surfaces of the arm the rounded swell of the biceps and the external and internal bicipital furrows are the most important landmarks.

FIG. 595.



Antero-median surface of right arm, showing modelling on living subject.

The elevation of the biceps shades off superiorly into the narrower and less distinct prominence of the coraco-brachialis where it comes into view below and beneath the anterior axillary fold. Inferiorly it narrows externally and merges into the biceps tendon, easily seen passing into the forearm in the deep interval between the rounded supinator and extensor mass on the radial side and the pronator and flexor mass on the ulnar side (Fig. 595). Internally the broader flat slip of bicipital fascia—the inner tendon—may be seen with its sharp upper edge when the forearm is semi-flexed and the biceps is in strong action. The outer bicipital furrow indicates the position of the subcutaneous cephalic vein. The inner and deeper furrow marks the line of the basilic vein (subcutaneous in its lower half, then subfascial), of the median nerve and the brachial vessels, and in its upper half of the ulnar nerve. To the outer side of the outer furrow from above downward lie the deltoid, the outer head of the triceps, the outer portion of the brachialis anticus and the brachio-radialis, and the common extensor mass (Fig. 596). To the inner side of the inner furrow are seen the coraco-brachialis, the long head and then the inner head of the triceps, the brachialis anticus, and the pronato-flexor mass.

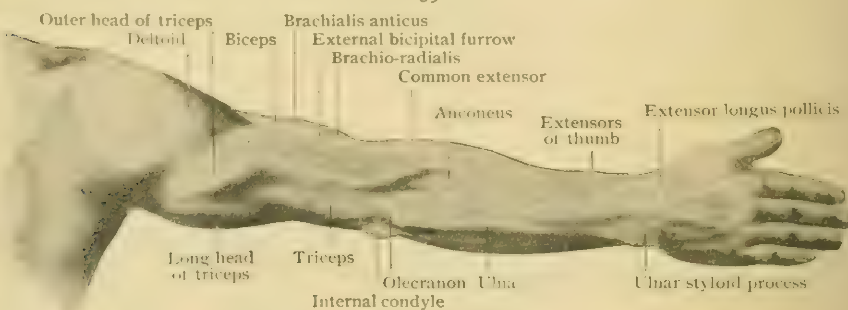
At the bend of the elbow anteriorly the subcutaneous veins are often visible. Their arrangement is sufficiently described and figured elsewhere (page 892, Fig. 764). The bicipital fascia passes between the median basilic vein and brachial artery, and, by springing from the inner edge of the biceps tendon, makes that edge

less distinct to both sight and touch than the outer edge. Just within the inner edge is the brachial artery and farther in the median nerve.

The fold of the elbow is a transverse crease in the skin, seen in flexion, convex downward, and running from the tip of one condyle to the tip of the other. It lies above the line of the elbow joint. In dislocation of the radius and ulna backward the lower end of the humerus is below this crease; in fracture of the humerus above the condyles the lower end of the upper fragment is either on a line with or above the crease. This relation will not be demonstrable in the presence of much swelling, as this fold is then obliterated.

On the front of the forearm, below the apex of the triangular space resulting from the convergence of the two muscular masses descending from the condylar regions, there are no salient surface landmarks, and none of great practical importance until the wrist is reached. Many of those of that region and of the hand have been described (pages 228, 229, 230, 320). It should, however, be noted that, instead of being flattened from before backward and widest from side to side as when in the supine position, the forearm when the hand is pronated becomes rounded and its antero-posterior slightly exceeds its lateral thickness (Thomson). This is due to the fact that the tendons of the supinator and extensor masses are held in grooves in the lower end of the radius by the posterior annular ligament, and are thus carried towards the ulna when the radius moves in that direction.

FIG. 596.



Posterior surface of arm shown in preceding figure.

Of the two transverse furrows on the flexor surface of the wrist the lower is the more marked. It is almost three-quarters of an inch below the summit of the upward curve of the wrist-joint, is on the line of the intercarpal joint and of the upper border of the anterior annular ligament, and is about a half-inch above the carpo-metacarpal joint. At the wrist the palmaris tendon—when present—is made prominent by extending the digits, slightly flexing the wrist, and closely approximating the thenar and hypothenar eminences. To its radial side from within outward lie the median nerve, the tendon of the flexor carpi radialis, and the radial artery. To its ulnar side lie first the rounded elevation made by the flexor sublimis tendons, then the ulnar artery, and then the flexor carpi ulnaris tendon, made easily palpable, although not very prominent, by strong flexion of the wrist and little finger.

On the postero-lateral aspect of the forearm may be seen:

1. The elevation of the anconeus, triangular in shape, to the radial side of the posterior subcutaneous surface of the olecranon and separated from the common extensor mass by a well-defined depression. This muscle and the expansion of the triceps tendon that covers it are of great value in the movement of extension of the forearm after excision of the elbow.

2. The curved border of the ulna (subcutaneous in supination), at the bottom of the *ulnar furrow*, between the flexor carpi ulnaris and the common extensor group, is easily accessible for examination through its whole length (page 289).

3. The very important depression just below the external condyle and external to the olecranon has been described (page 296).

4. The oblique elevation beginning at the lower third of the forearm in the interval left by the divergence of the supinator and the common extensor muscles, and running downward and outward, to be lost on the posterior surface of the thumb, represents the extensors of the thumb crossing over the tendons of the extensores carpi radialis longior and brevior to their points of insertion (Fig. 582).

5. The bony points to be seen and felt at the elbow and wrist have been described in their practical relations in connection with the bones and joints (pages 287, 296, 308, 320, 330). The tendon most easily identified on the dorsum of the wrist is that of the extensor longus pollicis when the thumb is strongly extended and abducted. It is the posterior or inner boundary of the hollow at the base of the thumb (*vide infra*), and its groove in the lower end of the radius is about the middle of the posterior surface and just to the ulnar side of the prominent middle thecal tubercle,—a useful landmark (page 296). The tendon, just before it reaches the radius, corresponds approximately to the scapho-semilunar joint.

The surface markings of the palm of the hand are often valuable landmarks.

The most important are: (1) The triangle called the "hollow of the hand," the "cup of the palm," etc., the base of which corresponds to the three elevations opposite the interdigital clefts,—formed by protrusion of fat between the flexor tendons and the digital slips of the palmar fascia and by the distal extremities of the lumbricales,—and seen best when the metacarpo-phalangeal joints are extended and the interphalangeal joints are flexed. The sides of the triangle are formed by the thenar and hypothenar eminences. Over this palmar hollow the intimate connection of the skin and fascia is of practical importance (page 613). (2) The chief cutaneous creases (Fig. 597) are four in number: (*a*) from just above the apex of the palmar triangle to the radial side of the hand above the base of the index-finger; (*b*) from the lower end of *a* to a point a little above the middle of the ulnar border of the palm, which it does not quite reach; (*c*) from about the junction of the lower fourth with the upper three-fourths of the ulnar border of the palm to a point a little above the cleft between the index and middle fingers; (*d*) from *b* to *c*, often extending upward towards the wrist and downward towards the base of the middle finger. *a* and *d* are longitudinal, the former being caused by adduction of the first metacarpal, the latter by adduction of the fifth metacarpal bone, both movements being towards the mid-line of the hand; *b* and *c* are transverse, and are produced chiefly by flexion (*b*) of the first and second (*c*) of the three inner metacarpo-phalangeal joints.

a represents the inner border of the thenar eminence and therefore, approximately, of the outer group of the short muscles of the thumb and the inner margin of the fascia intervening between them and the palmar space through which run the flexor tendons. It intersects the deep palmar arch at about the highest point where it crosses the metacarpal bone of the middle finger.

b, at the centre of the palm, where it is intersected by *d*, crosses the same metacarpal bone a line or two below,—*i.e.*, nearer the fingers than the superficial palmar arch, which runs about on a curved line from the lower border of the thumb, when it is at right angles to the hand, to the pisiform bone. The deep palmar arch is from a quarter to a half an inch nearer the wrist.

c represents the upper limits of the synovial sheaths of the flexor tendons of the index, middle, and ring fingers, is a little above the division of the palmar fascia into the digital slips and the bifurcation of the digital arteries, crosses the necks of the three inner metacarpal bones, and is as much above the corresponding metacarpo-phalangeal joints as they are above the webs of the fingers.

d, at its upper portion, irregularly outlines the outer border of the hypothenar eminence,—*i.e.*, of the short muscles of the little finger and of the fascia separating them from the central space of the palm,—but it is the most irregular and unimportant of these creases. The transverse folds on the palmar surfaces of the fingers correspond, the highest to the web of the fingers,—*i.e.*, from one-half to three-quarters of an inch below the metacarpo-phalangeal joint,—the middle to the proximal interphalangeal joint, and the lowest to a line a little above the distal interphalangeal joint. On the thumb the line of the radial side of the index-finger, if continued upward, almost coincides with the higher of the creases, which crosses the

metacarpo-phalangeal joint obliquely. The lower crease corresponds to the interphalangeal joint. The papillary ridges of the skin covering the terminal phalanges assume varied curves and form patterns,—immutable and characteristic in the individual,—impressions of which have been used of late years for purposes of identification of criminals.

On the dorsum of the hand the hollow at the base of the thumb (the so-called "snuff-box") is bounded externally (radially) by the tendon of the extensor of the

FIG. 597.

Surface markings of right palm.

metacarpal bone of the thumb and the short extensor, and internally by the tendon of the long extensor (Fig. 582). The radial artery, a large vein,—cephalic vein of the thumb (Treves),—and the inner division of the radial nerve cross this space. Beneath it are the scaphoid and trapezium and the articulation between the latter and the first metacarpal bone.

The abductor indicis muscle makes a distinct fusiform prominence when the thumb is adducted. The tendons of the common extensor and of the extensor of the little finger and the slip connecting them may be seen.

It should be remembered that the "knuckles" are at each joint, the distal extremities of the proximal bones entering into the articulation.

THE MUSCLES OF THE LOWER LIMB.

In describing the muscles of the lower limb a classification similar to that which was employed for the upper limb muscles will be followed. Owing, however, to the firm articulation of the innominate bones to the sacrum, the muscles extending between the axial skeleton and the pelvic girdle are greatly reduced, and those (such as the psoas) which might be included in this group are continued to the femur, and for present purposes are more conveniently grouped with the muscles extending from the girdle to the femur.

There is also, in the lower limb, a greater number of muscles passing over two joints; indeed, many of the muscles which are inserted into the upper portions of the leg bones take their origin from the pelvic girdle. Most of these seem to be, primarily, members of the femoral group of muscles and will be so classified in the succeeding pages, but one (the gracilis), at least, appears to belong to the group extending from the girdle to the femur.

THE MUSCLES EXTENDING FROM THE PELVIC GIRDLE TO THE FEMUR.

(*a*) THE PRE-AXIAL MUSCLES.

1. Psoas magnus.
2. Iliacus.
3. Pectineus.
4. Gracilis.
5. Adductor longus.
6. Adductor brevis.
7. Adductor magnus.
8. Quadratus femoris.
9. Obturator externus.
10. Obturator internus.
11. Gemelli.

1. Psoas Magnus (Fig. 598).

Attachments.—This muscle (**m. psoas major**) *arises* from the sides of the bodies of the twelfth thoracic and all the lumbar vertebræ and from the transverse processes of the lumbar vertebræ. Its fibres pass directly downward and slightly forward over the superior ramus of the pubis and are *inserted* by a tendon, in common with the iliacus, into the lesser trochanter of the femur.

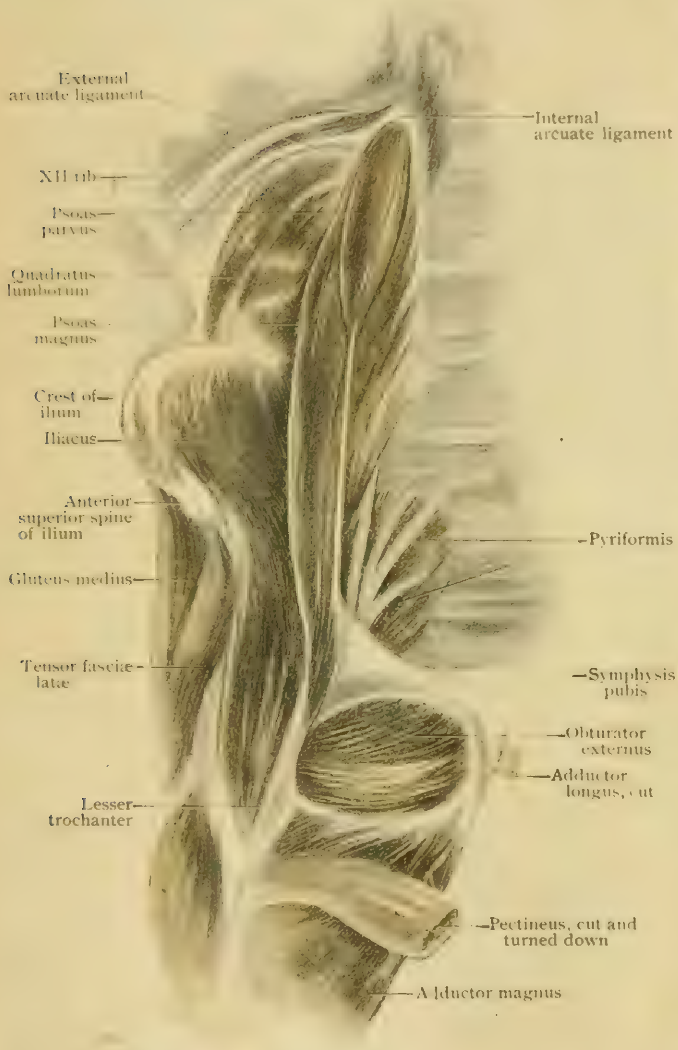
Nerve-Supply.—By branches from the lumbar plexus from the second, third, and fourth lumbar nerves.

Action.—To bend the spinal column laterally and to flex the body and pelvis upon the femur. Acting from above, it flexes the thigh and rotates it outward.

Relations.—The psoas magnus lies along the side of the lumbar vertebræ, resting upon their transverse processes and the medial portion of the quadratus lumborum. Extending as high as the last thoracic vertebra, it passes beneath the internal arcuate ligament, or medial lumbo-costal arch, of the diaphragm, and below it passes beneath Poupart's ligament to reach the thigh. In its abdominal portion it is in relation ventrally with the peritoneum, on the right side with the ascending colon and duodenum, and on the left side with the descending colon and pancreas. The inner border of the kidney overlaps the lateral portion of the muscle, and the ureter and spermatic (or ovarian) arteries descend obliquely along it. The inferior vena cava lies in front of the right muscle. The nerves formed by the lumbar plexus perforate the muscle, and the genito-crural nerve passes down on its anterior surface. In the pelvis the external iliac vessels lie along its medial border, and it is crossed, just before it passes beneath Poupart's ligament, by the vas deferens. In the thigh it forms a portion of the floor of the femoral or Scarpa's triangle, and lies between the iliacus and pectineus muscles, behind the femoral vessels. As the tendon which is common to it and the iliacus passes over the hip-joint it rests upon a rather large bursa (**bursa iliopectinea**); just above the insertion a second bursa (**bursa iliaca subtendinea**) intervenes between the tendon and the femur.

The psoas magnus appears to be formed by the union of a hyposkeletal trunk muscle with a femoral muscle, the remaining portions of which are represented by the iliacus and pectineus. It is interesting to note in this connection that in those mammalia in which the quadratus lumborum is well developed the psoas magnus is correspondingly weak, and *vice versa*.

FIG. 598.



Deep dissection of posterior body-wall and iliac fossa of right side.

The *psoas parvus* or *minor* (Fig. 598) is a long, flat muscle which lies upon the ventral surface of the psoas magnus, representing a separated portion of it, and is present in something over 50 per cent. of cases. It arises from the bodies of the last thoracic and first lumbar vertebræ and is inserted into about the middle of the ilio-pectineal line (linea terminalis) of the pelvis.

2. ILIACUS (Fig. 598).

Attachments.—The iliacus *arises* from about the upper half of the anterior surface of the ilium. Its fibres converge downward to form a common tendon with the psoas major, which is *inserted* into the lesser trochanter of the femur.

Nerve-Supply.—By the anterior crural nerve from the second, third, and fourth lumbar nerves.

Action.—To flex the thigh and rotate it slightly ~~inward~~; when the thigh is fixed, to flex the pelvis and trunk upon the femur.

Relations.—The iliacus covers the posterior wall of the false pelvis, and upon the right side has resting upon it the cæcum and on the left side the sigmoid colon. It is crossed obliquely by the external cutaneous and the anterior crural nerves; its inner border is covered by the psoas magnus. It passes beneath Poupart's ligament external to the psoas magnus, its relations in the thigh being identical with those of that muscle.

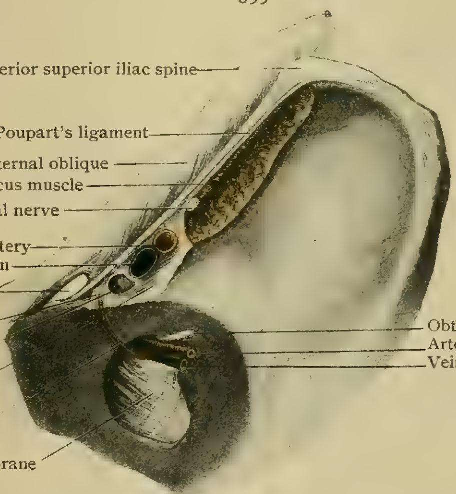
Variations.—The iliacus and psoas magnus are not infrequently extensively united, and the two muscles, together with the psoas parvus, when this is present, are frequently spoken of as the *m. ilio psoas*. The fibres of the iliacus which arise from the posterior superior spine of the ilium are often separated from the rest of the muscle to form an *iliacus minor*, which is inserted into the capsule of the hip-joint or into the anterior intertrochanteric line.

The Iliac Fascia.—This fascia is a strong sheet of connective tissue which covers the entire ilio-psoas. Above it is attached to the internal arcuate ligament of

the diaphragm, and thence descends over the anterior surface of the psoas. On reaching the level of the crest of the ilium, it is prolonged outward along that structure, where it is in connection with the lower edge of the transversalis fascia. It descends thence over the anterior surface of the psoas and iliacus, at the inner border of the former muscle passing over into the pelvic fascia. Below it is attached in its lateral two-thirds to Poupart's ligament, more medially it remains in contact with the ilio-psoas and passes down into the thigh behind the femoral vessels, separating these structures from the muscle and the anterior crural nerve and forming the posterior wall of the sheath for the femoral vessels. It thus divides the space beneath Poupart's ligament (Fig. 599) into a muscular compartment (**lacuna musculorum**) which contains the ilio-psoas muscle and the anterior crural and external cutaneous nerves, and a vascular compartment (**lacuna vasorum**) which contains the femoral artery and vein and the crural branch of the genito-crural nerve, its innermost portion, between the femoral vein and the free edge of Gimbernat's ligament, transmitting only a few loosely arranged lymphatic vessels and forming what is termed the *femoral ring* (**annulus femoralis**).

This ring (Fig. 599), which is covered over by a portion of the transversalis fascia, known as the *septum crurale* or *femorale*, is the upper end of a space, occu-

FIG. 599.



Dissection showing structures contained within the muscular and vascular compartments formed by attachments of iliac fascia.

pied by loose areolar tissue and lymphatic vessels, which extends a short distance downward along the inner side of the femoral vein, forming what is termed the *femoral canal.* Owing to the nature of its contents and to its upper end being closed only by the relatively thin septum femorale, this canal may allow of the escape of a portion of the intestine from the abdominal cavity downward into the thigh, producing a femoral hernia.

Medially the portion of the iliac fascia which forms the posterior wall of the sheath for the femoral vessels is continued over the anterior surface of the pectineus muscle (Fig. 1496), this portion of it being sometimes termed the *pectineal* or *ilio-pectineal fascia.* Above it is attached to the ilio-pectineal eminence and below becomes continuous with the deep layer of the fascia lata.

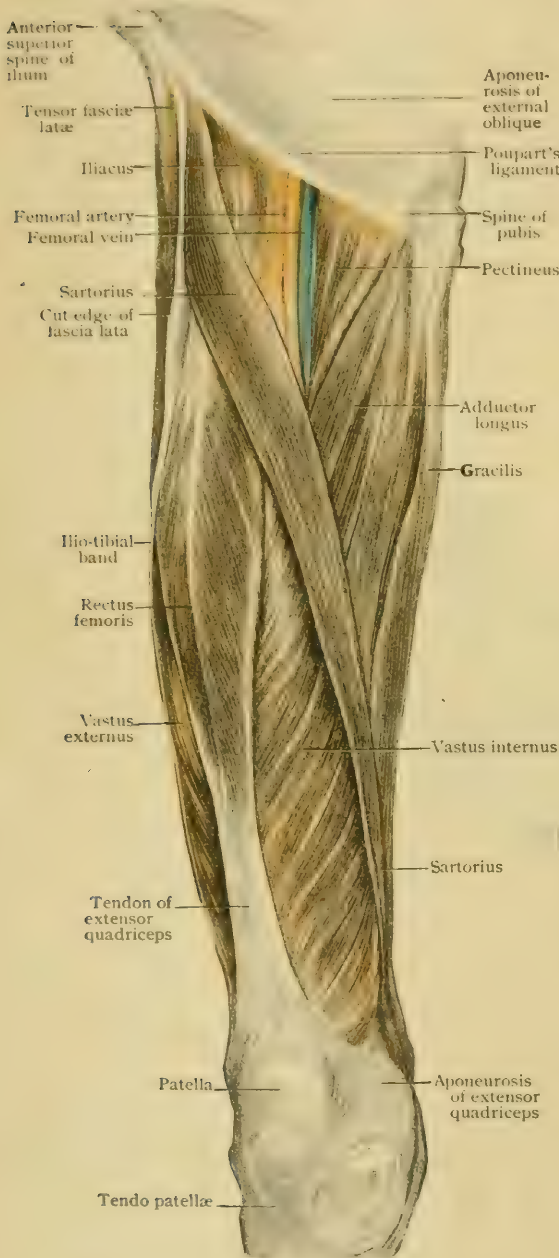
3. PECTINEUS (Fig. 600).

Attachments.—The pectineus *arises* from the anterior surface of the superior ramus and ilio-pectineal line of the pubis and passes downward and laterally to be *inserted* into the pectineal line of the femur, a bursa intervening between it and the bone.

Nerve-Supply.—From the anterior crural nerve by the second and third lumbar nerves.

Action.—To adduct and flex the thigh and rotate it slightly outward.

FIG. 600.



Muscles of right thigh, antero-median aspect.

Variations.—The fibres which innervate the pectineus sometimes pass to it wholly or partly by the obturator nerve.

4. GRACILIS (Fig. 600).

Attachments. — The gracilis is a long band-like muscle which *arises* from the anterior surface of the body and inferior ramus of the pubic bone. It descends along the inner surface of the thigh, passes behind the inner condyle of the femur, and then, bending slightly forward, is *inserted* into the inner surface of the tibia near the tuberosity, just above the semitendinosus and behind and beneath the expanded tendon of the sartorius.

Nerve-Supply. — By the anterior division of the obturator nerve from the second, third, and fourth lumbar nerves.

Action.—To adduct the leg and flex the thigh. It will also assist in rotating the leg inward, especially if the thigh be flexed.

5. ADDUCTOR LONGUS (Fig. 600).

Attachments. — The adductor longus *arises* from the anterior surface of the body and superior ramus of the pubis and passes downward and laterally to be *inserted* into about the middle third of the inner lip of the linea aspera of the femur.

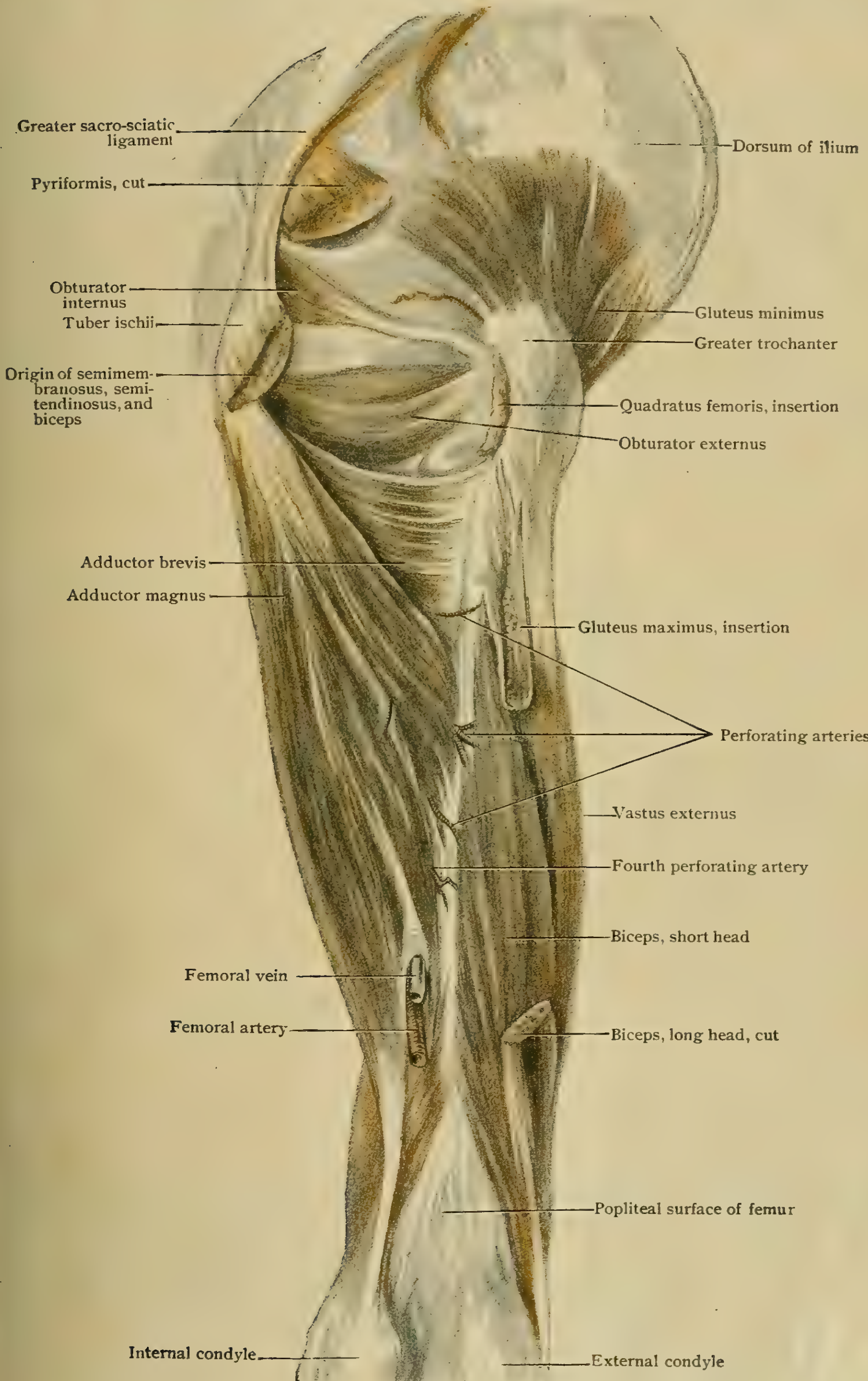
Nerve-Supply. — By the anterior division of the obturator nerve from the second and third lumbar nerves.

Action.—To adduct, flex, and outwardly rotate the thigh.

6. ADDUCTOR BREVIS (Fig. 601).

Attachments. —The adductor brevis *arises* from the body and inferior ramus of the pubic bone, below and partly external to the origin of the adductor longus. It passes laterally and obliquely downward to be *inserted* into the upper third of the medial lip of the linea aspera of the femur.

FIG. 601.



Deep dissection of posterior surface of right thigh.

Nerve-Supply.—By the anterior ramus of the obturator nerve from the third and fourth lumbar nerves.

Action.—To adduct, flex, and outwardly rotate the thigh.

7. Adductor Magnus (Fig. 601).

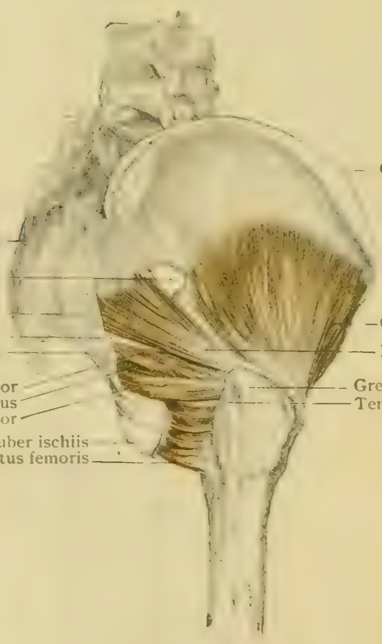
Attachments.—The adductor magnus *arises* from the inferior rami of the pubis and ischium, as far laterally as the base of the tuber ischii. Its anterior fibres are directed laterally and downward to be *inserted* into nearly the whole length of the inner lip of the linea aspera by a series of tendinous arches which give passage to the perforating branches of the profunda femoris artery on their way to the back of the thigh. Its posterior fibres converge downward to a strong tendon which is inserted into the adductor tubercle on the inner condyle of the femur.

Nerve-Supply.—By the posterior division of the obturator nerve from the third and fourth lumbar nerves.

Action.—To adduct the thigh.

Relations.—The adductor muscles, together with the gracilis, occupy the medial surface of the thigh, intervening between the extensor and flexor muscles. The adductor brevis and adductor longus enter into the formation of the floor of Scarpa's triangle (page 639), and from the apex of the latter the femoral vessels are

Fig. 602.



Deep dissection of right buttock, showing muscles attached to greater trochanter of femur.

continued downward upon the longus and magnus close to their insertion, and, together with the internal saphenous nerve, are bridged over by an aponeurotic membrane which passes from the longus and magnus to the surface of the vastus internus. By this membrane the space occupied by the vessels and nerve is converted into a closed passage-way termed *Hunter's canal* (**canalis adductorius**) (Fig. 606), the lower end of which corresponds to the interval (**hiatus tendineus**) between the tendons of the anterior and posterior portions of the adductor magnus.

The perforating branches of the deep femoral artery pierce the adductor magnus near its insertion, the first one passing above and the second below the adductor brevis, or both perforate that muscle also, while the third passes through the magnus a little above the hiatus tendineus.

Variations.—A separation of any of the adductor muscles into distinct portions may occur, and indeed the upper part of the anterior portion of the magnus is usually quite separate from the rest of the muscle and has been termed the *adductor minimus*. The posterior fibres of the magnus frequently receive their nerve-supply through the great sciatic nerve.

8. Quadratus Femoris (Figs. 602, 608).

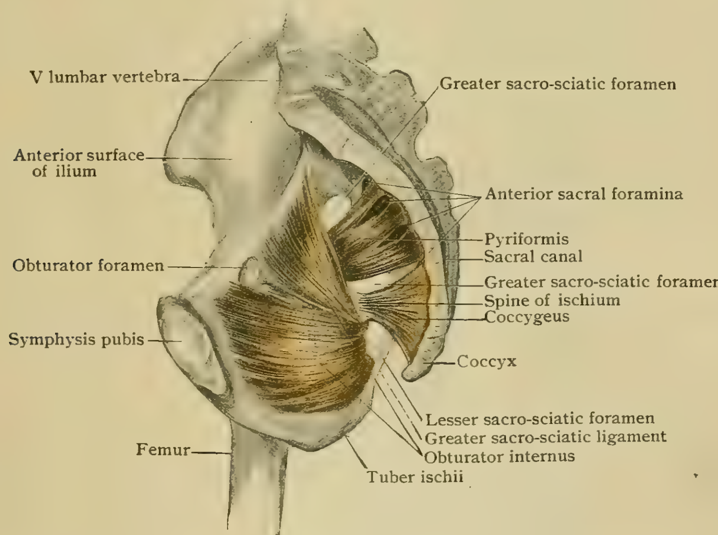
Attachments.—The quadratus femoris *arises* from the lateral border of the tuber ischii and passes almost directly outward to be *inserted* into the femur along the linea quadrati, which extends a short distance downward from about the middle of the intertrochanteric line.

Nerve-Supply.—By a special nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To rotate the thigh outward.

Relations.—The quadratus femoris is concealed by the lower portion of the gluteus maximus, and its posterior surface is crossed by the great and small sciatic nerves. Beneath it lie the obturator externus and the termination of the internal

Fig. 603.



Dissection of right postero-lateral wall of pelvis from within, showing pyriformis and obturator internus muscles.

circumflex artery. Its upper border is in contact with the gemellus inferior and its lower border with the adductor magnus.

Variations.—The muscle is not infrequently apparently absent, being fused with the adductor magnus.

9. Obturator Externus (Figs. 552, 601).

Attachments.—The obturator externus, a thick triangular muscle, *arises* from the anterior surface of the lower half of the obturator membrane and from the rami of the pubis and ischium which bound the lower half of the obturator foramen. The fibres are directed outward, and converge to a rounded tendon which is *inserted* into the floor of the digital fossa of the femur.

Nerve-Supply.—By the posterior division of the obturator nerve from the third and fourth lumbar nerves.

Action.—To rotate the thigh outward.

10. Obturator Internus (Figs. 602, 603).

Attachments.—The obturator internus *arises* from (1) the inner surface of the rami of the pubis and ischium which bound the obturator foramen, (2) from the

smooth surface of bone immediately behind the foramen, corresponding to the acetabulum externally, and (3) from the whole of the inner surface of the obturator membrane. Its fibres, passing downward and backward, converge to a strong tendon, which gains the lesser sacro-sciatic foramen, and there, bending around the margin of the foramen, a bursa (**bursa m. obturatoris interni**) intervening between the tendon and the bone, passes outward through the foramen to be *inserted* into a facet on the inner surface of the greater trochanter of the femur just above the digital fossa.

Nerve-Supply.—By a special nerve from the first, second, and third sacral nerves.

Action.—To rotate the thigh outward.

11. Gemelli (Fig. 602).

Attachments.—The gemelli are two slender muscles which lie one on either side of the tendon of the obturator internus. The *gemellus superior arises* from the spine of the ischium and the *gemellus inferior* from the upper part of the tuber ischii. Both muscles are *inserted* into the inner surface of the greater trochanter of the femur along with the obturator internus.

Nerve-Supply.—The superior gemellus by the nerve to the internal obturator from the fifth lumbar and first and second sacral nerves; the inferior by the nerve to the quadratus femoris from the fourth and fifth lumbar and the first sacral nerves.

Action.—To assist in rotating the thigh outward.

Variations.—One or other of the gemelli, usually the superior, is occasionally wanting. This is very probably due to fusion with adjacent muscles, the gemellus superior with the pyriformis and the inferior with the quadratus femoris.

(*b*) THE POST-AXIAL MUSCLES.

1. Gluteus maximus.
2. Tensor fasciæ latæ.
3. Gluteus medius.
4. Gluteus minimus.

1. Gluteus Maximus (Figs. 604, 607).

Attachments.—The gluteus maximus is an exceedingly thick, coarse muscle which forms the principal mass of the buttock. It *arises* from the lateral surface of the posterior portion of the ilium, behind the superior gluteal line, from the posterior surface of the sacrum and coccyx, and from the posterior sacro-iliac and greater sacro-sciatic ligaments. The fibres pass laterally and downward, the upper ones curving over the lateral surface of the greater trochanter of the femur and the lower ones over the tuberosity of the ischium, and are *inserted* by a broad tendon partly into the ilio-tibial band of the fascia lata and partly into the gluteal tuberosity of the femur.

Nerve-Supply.—By the inferior gluteal nerve from the fifth lumbar and first and second sacral nerves.

Action.—To draw the thigh backward and rotate it slightly outward. Acting from below, it extends the trunk.

Relations.—The gluteus maximus is covered by the upper posterior portion of the fascia lata. It covers the gluteus medius, pyriformis, obturator internus, gemelli, quadratus femoris and the origin of the hamstring muscles, and also the gluteal, sciatic, and pudic vessels and nerves.

It is separated from the lateral surface of the trochanter major by a large bursa (**bursa trochanterica m. glutaei maximi**), two or three additional small bursæ (**bursae glutaeofemorales**) separating the lower portion of the muscle from the shaft of the femur. A bursa is also frequently present beneath the muscle where it passes over the ischial tuberosity (**bursa ischiadica m. glutaei maximi**).

Variations.—The lower border of the gluteus maximus is occasionally separated from the rest of the muscle, forming what may be termed the *coccygeo-femoralis*, and it occasionally receives a slip from the ischial tuberosity, which has been named the *ischio-femoralis*.

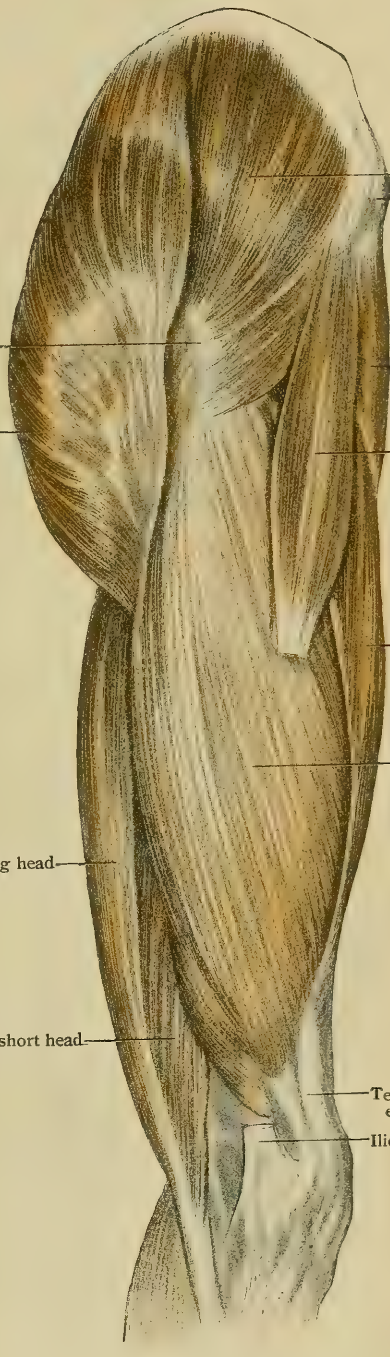
2. Tensor Fasciæ Latæ (Figs. 600, 604).

Attachments.—The tensor fasciæ latæ, also termed the *tensor vaginæ femoris*, is a flat muscle which *arises* from the crest of the ilium, immediately behind the anterior superior spine, and passes downward and slightly backward to be *inserted* into the upper portion of the ilio-tibial band of the fascia lata.

Nerve-Supply.—By the superior gluteal nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To tense the fascia lata and at the same time to flex the thigh and rotate it slightly inward.

Fig. 604.



Muscles of right thigh, lateral aspect.

3. Gluteus Medius (Figs. 604, 609).

Attachments.—The gluteus medius *arises* from the outer surface of the ilium, between the superior and middle gluteal lines. Its fibres pass downward, converging to a tendon which is *inserted* into the lateral surface of the great trochanter of the femur near its summit.

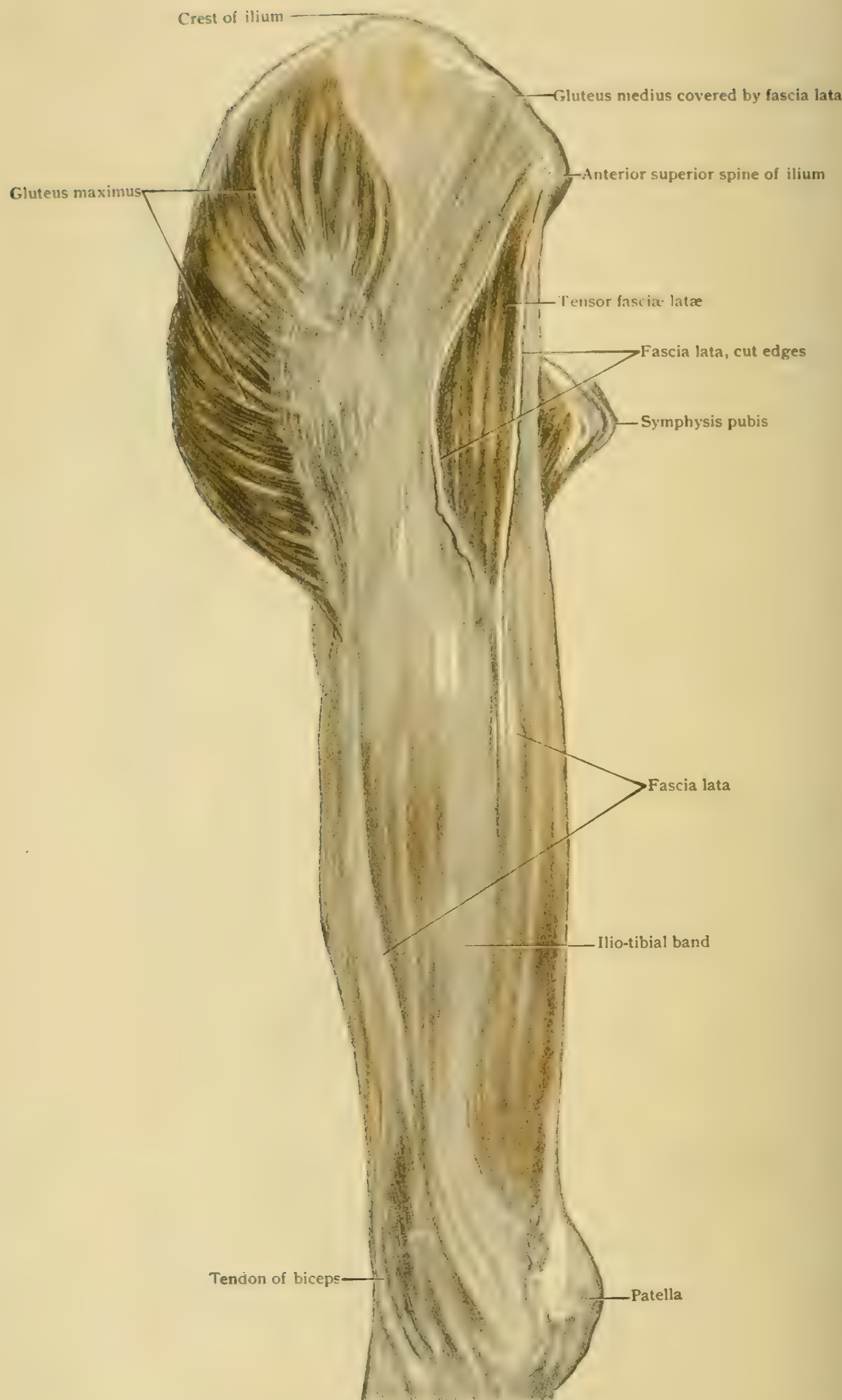
Nerve-Supply.—By the superior gluteal nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To abduct the thigh and by its stronger anterior fibres to rotate it inward. Acting from below, to flex the pelvis laterally.

Relations.—The anterior portion of the muscle is covered by the fascia lata and the tensor fasciæ latæ, the posterior portion by the gluteus maximus. Beneath it are the gluteus minimus and the superior gluteal vessels and nerve, its tendon passing over that of the pyriformis near its insertion.

A bursa (**bursa trochanterica m. glutaei medii anterior**) is interposed between the

Fig. 605.



Lateral surface of right thigh invested by fascia lata.

tendon of the muscle and the upper part of the great trochanter, and another (**bursa trochanterica m. glutaei medii posterior**) is usually present between the tendon and that of the pyriformis.

4. GLUTEUS MINIMUS (Figs. 601, 602).

Attachments.—The gluteus minimus is the most deeply situated of the gluteal muscles. It *arises* from the lateral surface of the ilium, between the middle and inferior gluteal lines, and passes downward and laterally to a strong tendon which is *inserted* into the anterior surface of the great trochanter of the femur.

Nerve-Supply.—By the superior gluteal nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To abduct the thigh and, acting from below, to flex the pelvis laterally.

Relations.—Superficially it is covered by the gluteus medius and crossed by the superior gluteal vessels and nerve. Deeply it rests upon the capsule of the hip-joint. A bursa (**bursa trochanterica m. glutaei minimi**) is interposed between the tendon and the great trochanter.

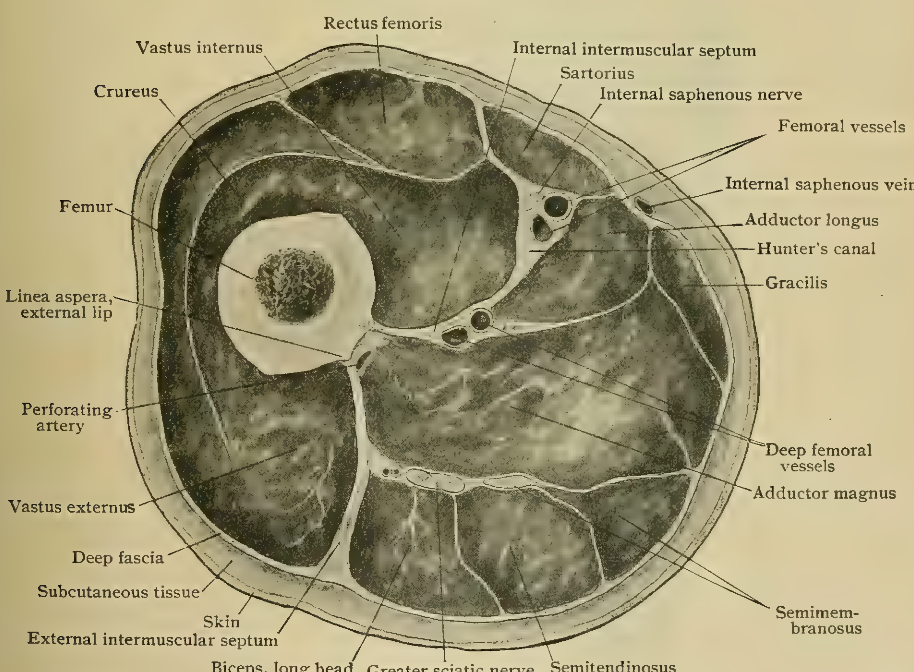
Variations.—The anterior portion of the muscle is sometimes distinctly separated from the rest, forming a muscle frequently present in the lower mammals and termed the *scansorius*.

THE FEMORAL MUSCLES.

Many of the muscles which belong to this group extend the entire length of the thigh, taking their origin, in whole or in part, from the pelvis.

The Fascia Lata (Fig. 605).—This, the deep fascia of the thigh, is a

FIG. 606.



Section across right thigh through Hunter's canal, seen from below.

strong layer which completely encloses the muscles of the thigh and covers the gluteal region. Its upper attachment, beginning from behind, is to the coccyx and sacrum ; thence forward along the entire length of the crest of the ilium and me-

dially along Poupart's ligament to the body of the pubis; thence it passes backward and downward along the inferior rami of the pubis and ischium to the ischial tuberosity, where it passes upon the greater sacro-sciatic ligament and so back to the starting-point. Below it is attached to the borders of the patella and becomes continuous with the fascia of the leg.

FIG. 607.

Superficial dissection of posterior surface of right buttock and thigh, showing muscles undisturbed.

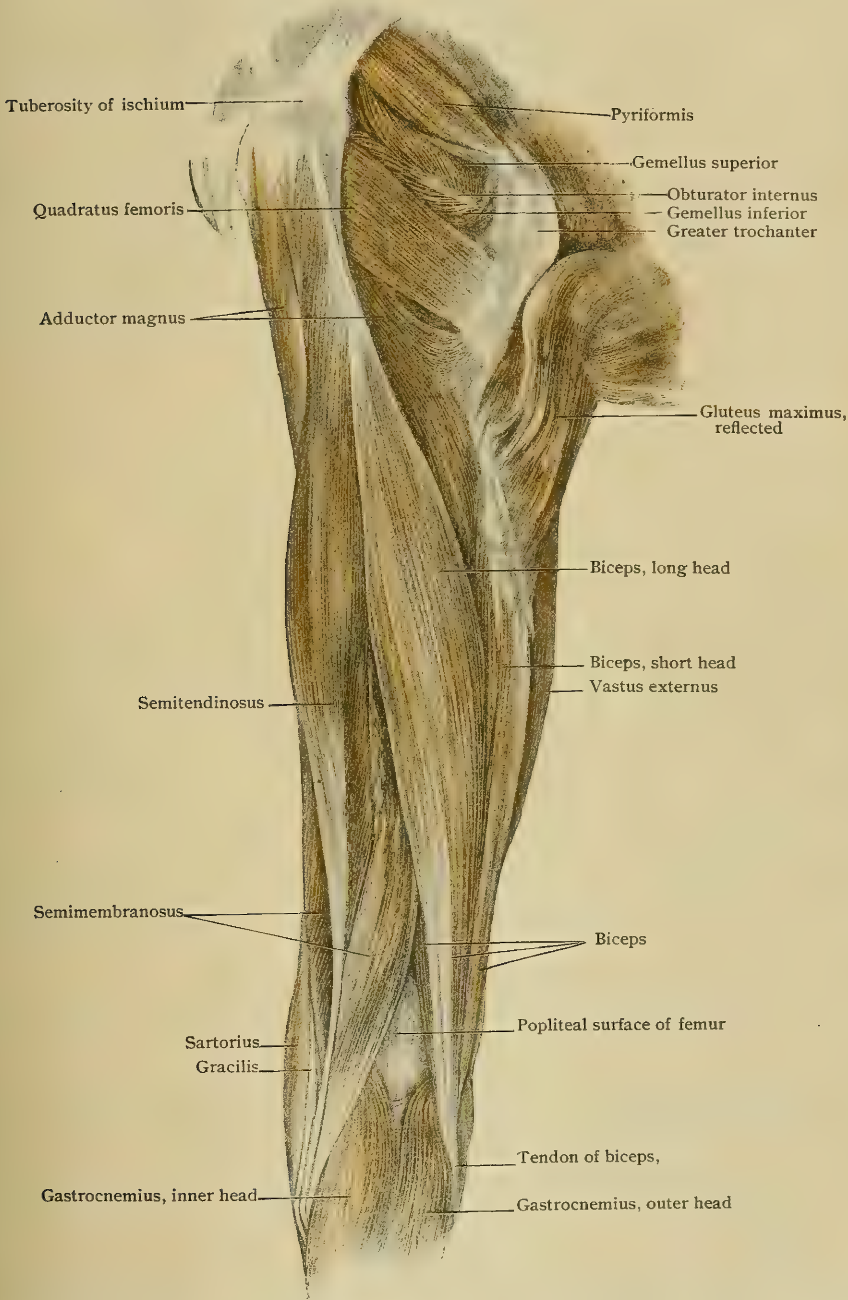
The fascia lata varies considerably in thickness in different regions. Over the gluteal region it is thin, but over the great trochanter of the femur it becomes greatly thickened, and this thickening is continued downward upon the lateral surface of the thigh (Fig. 605) as far as the external tuberosity of the tibia, forming what is termed the *ilio-tibial band* (**tractus iliotibialis**). This receives at its upper part the insertions of the tensor fasciæ latæ and part of the gluteus maximus, and from the posterior edge of its upper portion a much smaller and feebler band can be traced backward at first across and then below the lower portion of the gluteus maximus to the ischial tuberosity; it produces the *gluteal sulcus*.

In its lower posterior part, where it forms the roof of the popliteal space, the fascia is also somewhat thickened.

Anteriorly, just below the inner end of Poupart's ligament, a prolongation of the fascia passes deeply to join with the ilio-pectineal portion of the iliac fascia, and so assists in the formation of the sheath for the femoral vessels. Over an oval area, situated immediately external to where this prolongation, which is termed the *pubic portion* (Fig. 530) of the fascia lata, is given off, the fascia lata is quite thin and is perforated by the internal saphenous vein, superficial blood-vessels, and lymphatics;

whence it is termed the *cribriform fascia* (fascia cribrosa), the area which it covers being the *fossa ovalis.* The cribriform fascia is readily ruptured, the fossa ovalis then

FIG. 608.



Muscles of posterior surface of right buttock and thigh, gluteus maximus and medius having been reflected.

appearing as a perforation in the fascia lata, termed the *saphenous opening* (Fig. 523). The fossa ovalis lies immediately over (*i.e.*, in front of) the lower end of the femoral canal, and is consequently of importance in connection with femoral herniæ

(page 1773), which, descending in the canal, press against the thin fascia cribrosa and may cause it to bulge forward.

The part of the fascia lata lying to the outer side of the fossa ovalis, or the saphenous opening, is known as the *iliac portion* (Fig. 530), which at the lateral margin of the fossa ovalis, where the fascia cribrosa joins the fascia lata, is somewhat thickened to form a curved band termed the *falciform process* (**margo falciformis**). The latter is prolonged downward, as the *cornu inferius*, to join the pubic portion of the fascia lata, and upward, as the *cornu superius*, also termed the *femoral ligament* or *Hey's ligament*, which is somewhat stronger and continued medially to join the inner end of Poupart's and Gimbernat's ligaments.

Septa of connective tissue are continued from the deep surface of the fascia lata to the femur separating the various muscles of the thigh. Two are especially strong; one, the *internal intermuscular septum* (**septum intermuscularis medialis**), passing to the inner lip of the linea aspera, between the vastus internus and adductor magnus muscles, and the other, the *external intermuscular septum* (**septum intermuscularis lateralis**), to the external lip between the short head of the biceps and the vastus externus. To a certain extent these septa furnish surfaces of origin for some of the adjacent muscles.

(*a*) THE PRE-AXIAL MUSCLES.

1. Biceps femoris. 2. Semitendinosus.
3. Semimembranosus.

These muscles are popularly known as the *hamstring muscles.*

1. Biceps Femoris (Figs. 608, 609).

Attachments.—The biceps femoris takes its origin by two distinct heads. The *long head arises* from lower and inner facet upon the tuberosity of the ischium in common with the semitendinosus, while the *short head arises* from the whole length of the outer lip of the linea aspera and from the adjacent septum intermusculare. The fibres of both heads are directed downward, and at about the knee unite in a common tendon which passes behind the outer condyle of the femur and is *inserted* into the head of the fibula, bifurcating to embrace the long external lateral ligament of the knee-joint. Tendinous bands usually extend also from the tendon to the outer tuberosity of the tibia.

Nerve-Supply.—Both heads are supplied by the greater sciatic nerve. The fibres for the short head, however, pass, by way of the external popliteal division of the nerve, from the fifth lumbar and the first and second sacral nerves, while those for the long head pass by the internal popliteal division, coming from the first, second, and third sacral nerves.

Action.—To extend the thigh and flex the leg. When the leg is flexed the biceps will rotate it outward, and the long head acting from below assists in extending the trunk upon the hip-joints.

Relations.—The common tendon of origin of the biceps and semitendinosus is sometimes separated from the tendon of the semimembranosus by a bursa (**bursa m. bicipitis superior**). More rarely a bursa is to be found between the tendon of insertion of the biceps and the lateral head of the gastrocnemius, and almost constantly a bursa (**bursa m. bicipitis inferior**) separates the tendon of insertion from the fibular collateral ligament of the knee-joint.

Variations.—The most important variations of the biceps are an occasional absence of the short head and an extension of the insertion to the crural fascia. Both these anomalies are explained by the composition of the muscle, the two heads not only representing two originally distinct muscles, but, as is indicated by the nerve-supply, the long head is a portion of the pre-axial musculature of the thigh, while the short head belongs to the post-axial group. The comparative anatomy of the muscle shows that the short head is a modified representative of a muscle belonging to the gluteal set, which extended from the caudal vertebræ to the fascia of the crus and has only secondarily become united with the pre-axial muscle, sharing in its insertion.

FIG. 609.

Deeper dissection of posterior surface of right buttock and thigh, exposing semimembranosus and short head of biceps muscles.

2. Semitendinosus (Fig. 608).

Attachments.—The semitendinosus *arises* from the tuberosity of the ischium in common with the long head of the biceps. Its fibres extend downward to a long, slender tendon, which passes behind the inner condyle of the femur and then curves forward along with the tendon of the gracilis to be *inserted*, below that tendon and under cover of the expanded tendon of insertion of the sartorius, into the inner surface of the tibia near the tuberosity.

Nerve-Supply.—By the internal popliteal division of the greater sciatic nerve from the fifth lumbar and first and second sacral nerves.

Action.—To extend the thigh and flex and rotate inward the leg. Acting from below it will extend the trunk upon the hip-joints.

Relations.—A large bursa (**bursa anserina**) intervenes between the tendons of the gracilis and semitendinosus and the tibia.

3. Semimembranosus (Fig. 609).

Attachments.—The semimembranosus *arises* by a broad, flat tendon, which extends from upper and outer facet upon the tuberosity of the ischium downward along the outer border of the muscle to about the middle of the thigh. The muscle-fibres pass downward and inward from this tendon to a tendon of insertion, which occupies the medial border of the muscle and passes behind the inner condyle of the femur and curves forwardto the inner surface of the internal condyle of the tibia, into which it is *inserted*. An extension of the tendon of insertion usually passes downward and outward to the portion of the deep fascia of the leg which covers the popliteus muscle ; another band extends upward and outward towards the outer condyle of the femur, blending with and materially strengthening the posterior part of the capsular ligament of the knee-joint.

Nerve-Supply.—By the internal popliteal division of the greater sciatic nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To flex the leg and assist somewhat in rotating it inward. Acting from below it will extend the trunk upon the hip-joints.

Relations.—The semimembranosus is situated in front of the long head of the biceps and the semitendinosus and behind the adductor magnus. The greater sciatic nerve lies along its lateral border (Fig. 606). The tendon of insertion is separated from the inner head of the gastrocnemius by a bursa (**bursa m. semimembranosi medialis**), which often communicates with the synovial cavity of the knee-joint ; the **bursa m. semimembranosi lateralis** intervenes between the tendon and the inner condyle of the tibia.

(*b*) THE POST-AXIAL MUSCLES.

1. Sartorius.	4. Crureus.
2. Rectus femoris.	5. Vastus internus.
3. Vastus externus.	6. Subcrureus.

1. Sartorius (Fig. 610).

Attachments.—The sartorius is a long band-like muscle which *arises* from the anterior superior spine of the ilium and the adjacent part of the notch below it. It descends obliquely downward and inward across the front of the thigh, in the groove between the rectus femoris and the vastus internus, on the one hand, and the adductor muscles, on the other, and then passes directly downward behind the inner condyle of the femur. It finally bends forward to be *inserted* into the inner surface of the tibia near the tuberosity, covering the insertions of the gracilis and semitendinosus.

Nerve-Supply.—By the anterior crural nerve from the second and third lumbar nerves.

Action.—To flex the thigh and leg and to rotate the thigh outward ; when the leg is flexed, the muscle will assist in rotating the thigh inward.

Relations.—As it passes obliquely across the upper part of the thigh, the sartorius forms the lateral boundary of a triangular depression which is known as *Scarpa's triangle* (**trigonum femorale**). The inner boundary of this triangle is formed by the adductor longus, its base by Poupart's ligament, its floor by the ilio-psoas and pectineus and often to a slight extent by the adductor brevis, and its roof by the fascia lata and the cribriform fascia. The space so bounded is traversed from above downward, from the middle of its base to its apex, by the femoral vessels and the anterior crural and crural branch of the genito-crural nerve, and contains a number of lymphatic nodes. At its apex it is continuous with the adductor or Hunter's canal.

A mucous bursa (**bursa m. sartorii propria**) intervenes between the tendon of the sartorius and those of the gracilis and semimembranosus, and occasionally communicates with the bursa anserina (page 638).

The remainder of the post-axial musculature of the thigh is almost entirely represented by four large muscles, more or less separable above, but united below in a common tendon, which is inserted into the upper border of the patella, and through this and the ligamentum patellæ acts upon the tuberosity of the tibia. These muscles have been grouped together as the *extensor quadriceps femoris*, and include the rectus femoris, the vastus externus, the crureus, and the vastus internus.

FIG. 610.

Muscles of right thigh, anterior aspect.

2. RECTUS FEMORIS (Fig. 610).

Attachments.—The rectus femoris has a double origin, the one, or *straight head*, *arising* from the anterior inferior spine of the ilium, and the other, or *reflected head*, from the surface of the ilium a short distance above the acetabulum. The two heads give rise to a single tendon which descends for some distance along the front of the muscle and, in conjunction with a median septum, gives origin to the muscle-fibres. These present a bipinnate arrangement, and pass over below into the common tendon to be eventually *inserted* by the ligamentum patellæ into the tubercle of the tibia.

Nerve-Supply.—By the anterior crural nerve from the third and fourth lumbar nerves.

Action.—To flex the thigh and extend the leg. Acting from below it will flex the trunk on the hip-joints.

Relations.—The rectus femoris rests upon the capsule of the hip-joint above and the crureus below. A bursa frequently intervenes between the surface of the ilium and the head which is inserted above the acetabulum.

3. Vastus Externus (Fig. 610).

Attachments.—The vastus externus (**m. vastus lateralis**) *arises* from the anterior intertrochanteric line, the lateral surface of the greater trochanter, and the outer lip of the linea aspera. The fibres curve downward and inward to unite with the crureus and to be *inserted* into the common tendon.

Nerve-Supply.—By the anterior crural nerve from the third and fourth lumbar nerves.

Action.—To extend the leg.

4. Crureus (Fig. 606).

Attachments.—The crureus (**m. vastus intermedius**) lies below the rectus femoris and between the vastus externus and vastus internus. It *arises* from the anterior surface of the femur and passes downward into a flat tendon which is *inserted* into the common tendon a short distance above the patella.

Nerve-Supply.—By the anterior crural nerve from the third and fourth lumbar nerves.

Action.—To extend the leg.

5. Vastus Internus (Fig. 600).

Attachments.—The vastus internus (**m. vastus medialis**) is usually so blended with the crureus as to be hardly separable from it. It *arises* from the spiral line and from the inner lip of the linea aspera of the femur, the fibres curving downward and outward to be partly united with the crureus and partly *inserted* into the common tendon.

Nerve-Supply.—By the anterior crural nerve from the third and fourth lumbar nerves.

Action.—To extend the leg. Owing to the oblique direction of the femur downward and inward the action of the quadriceps femoris would be to draw the patella outward as well as upward, thus tending towards an outward dislocation of that bone. This is obviated, however, by the vastus internus, the bulk of whose fibres arise from the lower part of the femur and are directed more or less transversely outward to the inner border of the common tendon.

Relations.—The medial border of the vastus internus forms the outer wall of Hunter's canal (Fig. 606), the fascia which forms the roof of the canal extending across between this muscle and the adductor magnus.

6. Subcrureus.

Attachments.—The subcrureus (**m. articularis genu**) is frequently so inseparably blended with the crureus that it may well be regarded as the deepest layer of the latter rather than as a distinct muscle. It *arises* from the lower part of the anterior surface of the femur and passes downward to be *inserted* into the upper border of the capsule of the knee-joint.

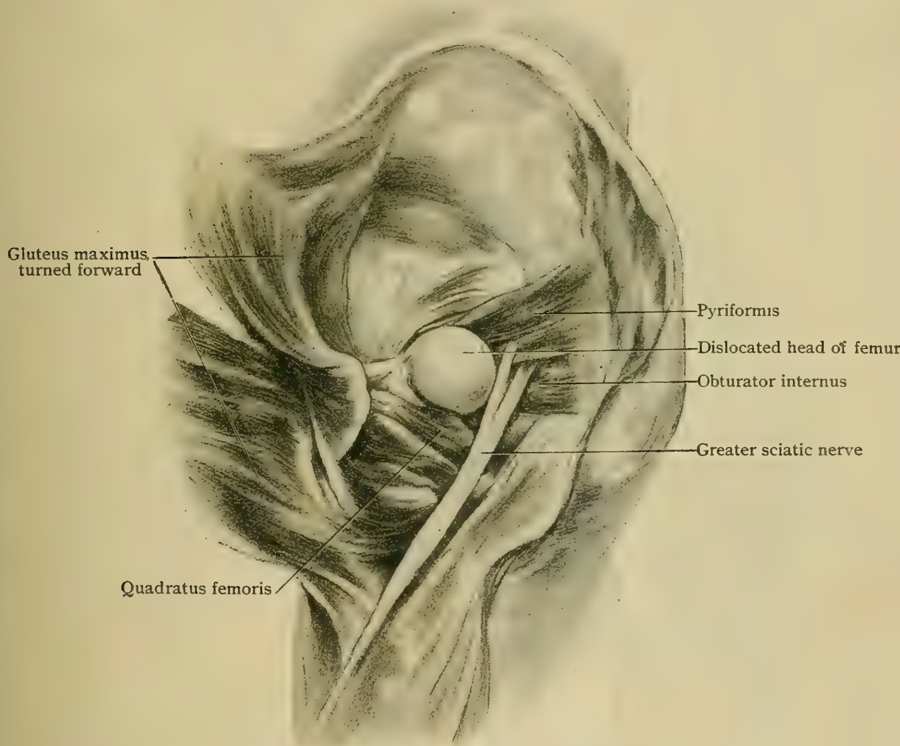
Nerve-Supply.—By the anterior crural nerve from the third and fourth lumbar nerves.

Action.—To tense the capsule of the knee-joint.

PRACTICAL CONSIDERATIONS: MUSCLES AND FASCIÆ OF THE BUTTOCKS, HIP, THIGH, AND KNEE.

1. **The Buttocks.**—The skin over this region is thick and is closely connected with the superficial fascia, which is abundant, loose, and contains much fat. The skin is richly supplied with nerves from the small sciatic, the external and the perforating cutaneous, the ilio-hypogastric, and the external branches of the posterior division of the lumbar and sacral nerves. It is poorly supplied with blood as compared with other cutaneous areas, and hence usually has a relatively low surface temperature. It is coarse, with numerous sebaceous follicles, and is the site of frequent minor forms of irritation,—chafes, bruises, etc.,—and is for these reasons a common seat of superficial

FIG. 611.



Dissection of posterior luxation of left femur towards dorsum of ilium.

furuncles, which, on account of its intimate union with the underlying fascia and its plentiful nerve-supply, are apt to be very painful.

The presence of a large quantity of poorly organized fat in the superficial fascia and the frequency of local irritation render the region a favorite seat of lipomata.

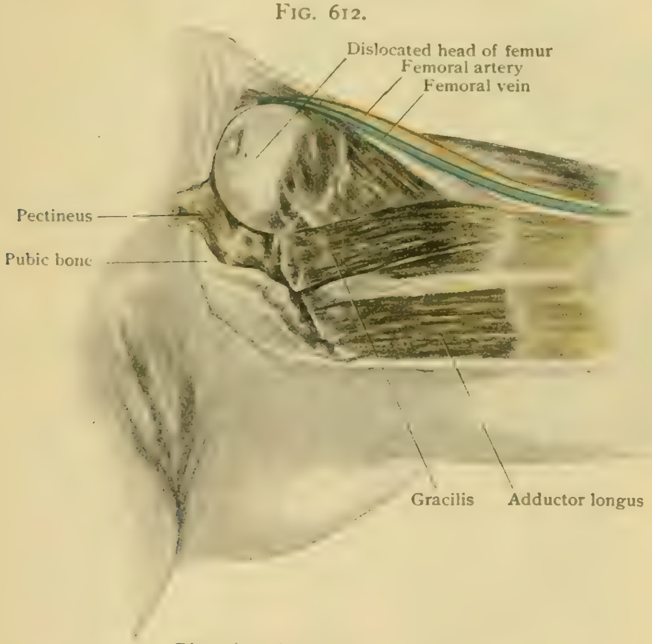
The laxity of the superficial fascia permits effusions of pus or of blood to attain exceptionally large dimensions, and this is encouraged by gravity in the usually dependent position of the part.

The deep fascia attached to the back of the sacrum and coccyx and to the crest of the ilium covers in the gluteus medius and holds it, with the gluteus minimus, in an osseo-fascial space, as the ilio-psoas is held anteriorly by the iliac fascia (page 624). The posterior space, however, is completely closed superiorly and is open only inferiorly, towards the thigh, and antero-internally, towards the sciatic foramina. Abscesses or extravasations of blood in this space may originate in, or may find their

way into the pelvic cavity; or, guided by gravity, they may travel long distances down the thigh before pointing. They are apt to be associated with much pain because of the compression of the gluteal and other branches of the sacral plexus between the bone anteriorly and the musculo-aponeurotic wall of the space posteriorly.

The gluteus maximus is embraced by a sheath formed by the splitting of this fascia into two layers, the superficial one of which is thinner and less dense than the deep layer. Abscess or hemorrhagic extravasation within the substance of that muscle is, therefore, likely to give more external evidence of its presence and to be less painful than if in or beneath the gluteus medius. The gluteus maximus itself may be ruptured by violent exertion in extending the pelvis and trunk on the thigh, the latter being fixed, as in raising a heavy weight on the back and shoulders while passing from a stooping to an erect position, or in carrying a similar burden upstairs, the pelvis and femur having then the same relative position at each upward step that they have when the thigh is vertical and the trunk and pelvis are flexed. In the erect position the muscle is relaxed. When it is paralyzed the patient can walk easily on a level, but has trouble in going upstairs or in exchanging a sitting for a standing posture. Wounds of the buttock without fracture of the bones may enter the pelvic cavity through the sacro-sciatic foramina, and Treves has recorded a case of stab wound of the buttock in which the patient died from peritonitis, the wound having involved the bladder and caused intraperitoneal extravasation of urine.

FIG. 612.



Dissection of pubic luxation of hip-joint.

A subgluteal triangle has been described (Guiteras), the boundaries of which are externally the femoral and trochanteric insertion of the gluteus maximus, internally the long head of the biceps, the tuber ischii, and part of the sacro-sciatic ligament, superiorly the pyriformis. The floor of the triangle is made by the external rotators and the adductor magnus. It is the region of aneurism of or occasional hemorrhage from the sciatic artery, of emergence of the sciatic nerve, and of one form of sciatic hernia, below the pyriformis. The "triangle" is an artificial one, and is mentioned merely as an aid to localization of the above structures.

The subgluteal bursæ are of considerable importance. One is found interposed between the trochanter and each of the gluteal muscles (page 630). Inflammation and enlargement of these bursæ will be followed by adduction and flexion of the thigh, because active extension of the thigh, in which the glutei aid, and rotation inward, putting them on the stretch, are painful. Flattening of the buttock and obliteration of the gluteo-femoral crease may follow atrophy of the muscles from disease (page 381). Caries of the trochanter has resulted from suppuration in these bursæ.

The bursæ over the tuberosities of the ischium frequently enlarge and may cause two solid symmetrical swellings—"weavers' bottom"—which require removal.

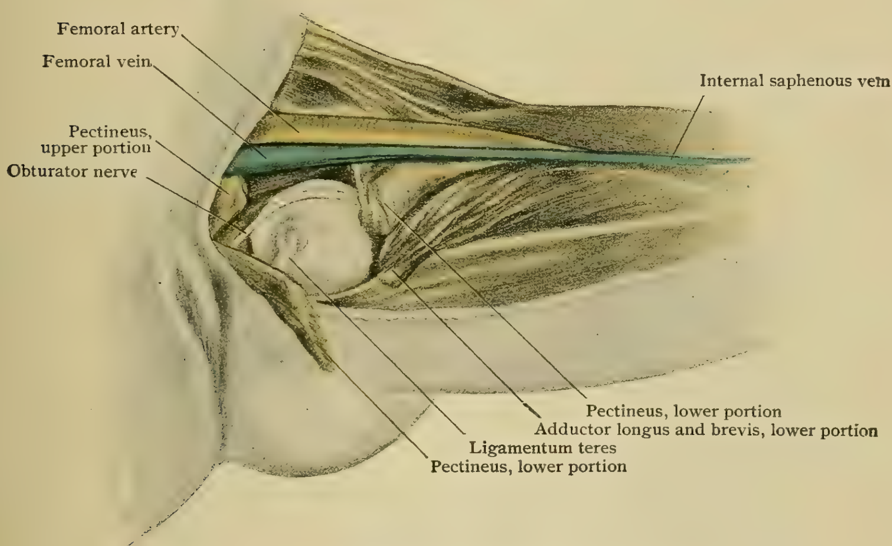
2. **The Hip and Thigh.**—The skin over the hip is less dense than over the buttock, and is still thinner below Poupart's ligament and in the region of Scarpa's

triangle. Over all the lower portion of the thigh it is loosely connected by abundant connective tissue with the fascia lata, its attachment being closest along the line of the external intermuscular septum, between the vastus externus and the hamstring muscles. It is coarse externally and thinner over the abductor surfaces. It is easily stripped up by effusions or retracted during operations.

The superficial fascia in the subinguinal region is in two layers, in the more superficial of which is the subcutaneous fat. The deeper layer is the denser, and on it lie the lymphatic nodes occupying the saphenous opening. It offers, however, in this region, but little resistance to the progress of pus towards the surface, as it is perforated—hence "cribriform fascia"—by the lymph-vessels passing from the superficial to the deep set of inguinal nodes, by the superficial epigastric and external pudic vessels, and by the internal saphenous vein to empty into the femoral.

Lipomata are not infrequent in this fascia, especially on the front, but sometimes on the back of the thigh, and on account of its laxity and of the absence of firm attachments of their capsules, are apt to travel downward by gravity.

FIG. 613.



Dissection of thyroid luxation of femur, showing muscles ruptured.

The deep fascia or fascia lata (page 633), attached above to the lower edge of the great sacro-sciatic ligament, the tuberosity and ramus of the ischium, the crest of the ilium, Poupart's ligament, and the body and ramus of the pubes, and below to the lateral margins of the patella and to the tibia, and continuous posteriorly with the deep fascia of the leg, forms an almost unbroken sheath around the thigh. Its continuity is interrupted only by the saphenous opening (page 635). It is of sufficient strength and density everywhere to influence the course of abscesses and to modify the surface appearance or feel of deep growths. A lipoma beneath the fascia lata may apparently have the density of a malignant growth. A psoas abscess (page 143), after it has followed the muscle under and below Poupart's ligament, usually perforates the sheath and the fascia lata and points external to the vessels at the upper part of the thigh; but after escaping from the sheath it may be unable to penetrate the fascia, and may be guided by it to the lower third of the thigh, the knee, or even as low as the leg or ankle.

The fascia has been torn or wounded, and, as it embraces the subjacent muscles so closely, the latter have bulged through the opening, appearing on the surface of the thigh as rounded elevations varying in size and tension with the position of the limb.

Rupture of the fascia has, in recorded instances, been associated with rupture of the ilio-psoas, the rectus, and the biceps femoris. The outer and inner intermuscular septa (page 636) are of less surgical importance than the corresponding structures in the arm, and have but little effect in limiting or determining the course of a cellulitis or an abscess.

On the outer side of the thigh, running from the forepart of the crest of the ilium above to the outer tuberosity of the tibia and the head of the fibula below, is the thickening of the fascia lata known as the ilio-tibial band, the dense, glistening fibres of which bridge over the supratrochanteric space between the summit of the trochanter and the iliac crest. Normally at this point the band offers distinct resistance to pressure with the fingers. In fracture of the neck of the femur, with shortening, it must be relaxed and less resistant (Allis), and this sign is of especial value in obscure cases of impacted fracture of the neck in which crepitus, preternatural mobility, and other of the conventional symptoms of fracture are lacking (pages 364, 367, 390).

The relations of the muscles about the hip to dislocation (Figs. 395, 396, pages 377, 378) and to hip disease (page 381) have been described. Suppuration affecting the iliacus or the ilio-psoas has also been dealt with (page 381).

Strains of the ilio-psoas muscle are not infrequent, and may, especially in children, give rise to a mistaken diagnosis of hip-joint disease. In sprains, however, the movements of the joint that do not affect the ilio-psoas will be painless and most of the other anatomical symptoms (page 380) will be absent.

The extensive bursa between the capsule of the hip-joint and the ilio-psoas muscle (*ilio-psoas bursa*) may enlarge and become visible at the front of the thigh below the middle of Poupart's ligament. The thigh will be found flexed from reflex irritation of the ilio-psoas and to lessen pressure on the bursa (page 381). As the latter not infrequently communicates with the hip-joint, infectious disease of one may extend to the other.

The adductors are also often strained or overworked, particularly during horseback exercise, and are sometimes sprained or stretched close to their pelvic origins. The latter injury may result in a sclerosis of one of the adductor tendons, possibly going on to true ossification, and producing a condition seen oftenest in cavalrymen, and known as "rider's bone."

Fractures of the femur situated below the neck (page 363) and above the condyles (page 366) are much influenced by muscular action, as might be expected from the number and strength of the muscles concerned. Three of these fractures may be considered in this relation:

1. Fracture just below the trochanters (subtrochanteric fracture). This is one of the most difficult of femoral fractures to manage because of the flexion, abduction, and outward rotation of the upper fragment, caused by the action of the ilio-psoas, the gluteus minimus and medius, the obturators, quadratus, pyriformis, and gemelli. The lower fragment is drawn upward by the rectus, gracilis, tensor fasciæ latæ, and sartorius, upward and inward by the adductors, upward and a little backward by the hamstrings. In the treatment, elevation and abduction of the thigh —*i.e.*, of the lower fragment—are often resorted to for obvious reasons.

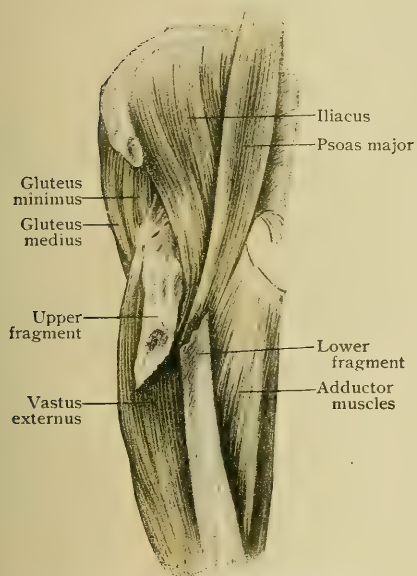
2. Fracture of the middle of the shaft is very frequent (page 365). It is usually moderately oblique from behind downward and forward. The upper fragment is almost always in advance of the lower fragment because (*a*) the fracturing force is more apt to be applied from in front and to the lower rather than the upper part of the thigh; (*b*) the weight of the limb in the supine position would favor a posterior position of the lower fragment; (*c*) the ilio-psoas tends to advance the upper fragment, and the adductor magnus and gastrocnemius draw the lower fragment somewhat backward (Fig. 614). There is often a forward angulation or bowing in the direction of the normal curve of the femoral shaft (page 365), thought to be due to the action of the adductors which subtend the arc of the curve.

The shortening is produced, as usual, by the muscles running from the pelvis to the thigh and leg.

3. Fracture just above the condyles (supracondylar fracture). This is usually the result of severe injury or of direct violence. It is commonly oblique from behind forward and downward. The fracture takes place at about the point of junction

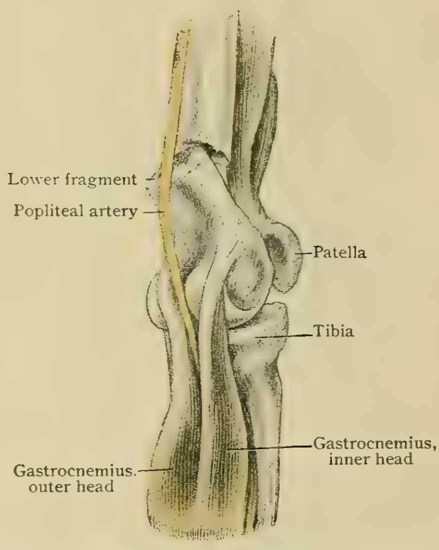
of the compact tissue of the shaft with the cancellated tissue of the expanded lower extremity. It is from one to two inches higher than the epiphyseal line. The same backward rotation of the lower fragment occurs as in disjunction of the epiphysis (page 365), and in both cases from the action of the gastrocnemius. In the fracture, however, the sharp lower end of the upper fragment is far more apt to project anteriorly than is the diaphysis in cases of epiphyseal disjunction. It is not infrequently entangled in fibres of the rectus and may lacerate the suprapatellar synovial pouch. The difference probably results from the character of the fracturing force, which in the epiphyseal accident is, in the majority of cases, hyperextension of the leg on the thigh. The action of the ilio-psoas tends to advance the lower end of the upper fragment, but must be feeble. The pectineus slightly and the adductors quite strongly draw it inward. The shortening is produced by the hamstrings, rectus, sartorius, etc. The most difficult element of the deformity to do away with is the posterior rotation of the lower fragment, which may also result in serious pressure upon or injury to the popliteal vessels and nerves. In setting such a fracture it may be necessary to relax the chief muscles concerned by flexing the thigh to a right angle with

FIG. 614.



Dissection of fracture of upper third of right femur, showing forward and inward displacement.

FIG. 615.



Dissection of fracture of lower third of left femur, showing displacement of popliteal artery by lower fragment.

the pelvis to relax the ilio-psoas, drawing the knee inward a little to relax the adductors, and flexing the leg on the thigh to relax the gastrocnemius, and then to make extension by means of the forearm placed in the ham. Not uncommonly the displacement recurs so obstinately that it becomes necessary to treat the case with the leg fully flexed on the thigh, and even to divide the tendo Achillis.

3. **The Knee.**—The skin over the front of the knee is dense, coarse, and loose, qualities that diminish the gravity of the frequent injuries to the integument itself and also serve to protect the underlying joint, "especially in stabs with bluntish instruments" (Treves) and, in fact, in many forms of accident in which the free movement of the skin over the subjacent structures serves to make the application of force to the latter much less direct.

In full flexion the skin, in spite of its laxity, is drawn tensely over the patella, and a fall may result in an extensive wound.

The relation of the cutaneous nerves and vessels over the knee to those supplying the articulation should be studied in connection with the common application of counterirritants or of blisters to the region.

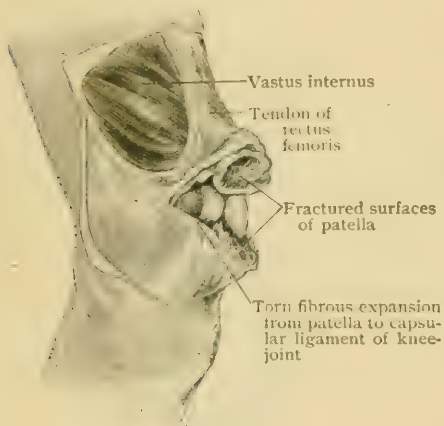
The quadriceps tendon is separated from the femur by a large bursa, which, in from 70 to 80 per cent. of cases, communicates with the knee-joint and may be involved in its diseases. When separate from the joint and distended by effusion, it may be mistaken for synovitis of the knee, but the patella will not be floated up and the concavities at either side of that bone and those at the sides of the ligamentum patellæ will not be effaced.

The prepatellar bursa, separating the patella from the skin, is frequently enlarged in persons who spend much time kneeling,—"housemaid's knee."

The bursa between the ligamentum patellæ and the tubercle of the tibia may be enlarged or inflamed, and is then apt to be painful on account of its compression between two non-distensible structures, the bone and the ligament. The little pad of fat (page 400) between the tubercle and the ligament, which protrudes at the sides of the latter when the quadriceps extensor is in action (page 405), should not be mistaken for enlargement of this bursa.

Posteriorly—over the ham—the skin is thinner and less movable. The deep fascia—here the popliteal fascia—is dense and exerts marked obstruction to the extension of abscess, growth, or aneurism towards the surface, in this way causing severe pain from the pressure upon the nerves that run through the space. As the latter is open above and below, abscesses may extend in either direction.

Fig. 616.



Dissection of fracture of patella.

Pus or infection may be guided to the subfascial region in the ham from the pelvis or the buttock by the great sciatic nerve, or from the thigh by the femoral vessels, or from the leg by the short saphenous vein, or by the deeper vessels and the lymphatics.

The relations of the fascia and muscles of the thigh to the patella and the knee-joint and to their injuries and diseases have been sufficiently described (Figs. 424–430, pages 409–418).

The hamstring tendons are not infrequently divided, as, for reasons already given, ankylosis of the knee-joint is usually in the position of flexion (page 412). They are made very tense when the pelvis is strongly flexed on the thigh, the knee remaining extended. They may be ruptured if excessive force is applied under these circumstances.

The biceps tendon is easily felt on the outer side of the ham, with the peroneal nerve, also readily palpable, lying against its inner and posterior border. At the inner side of the ham the semitendinosus tendon is nearer the mid-line, nearer the surface, more easily outlined, thinner, and more cord-like than the semimembranosus tendon, which is the most deeply situated of the three hamstrings. The line for dividing these tendons is preferably a little above the level of the knee-joint and about opposite the most salient parts of the femoral condyles.

In the popliteal region there are several bursæ: (*a*) the largest is between the inner head of the gastrocnemius and the semimembranosus and the inner condyle of the femur, extending downward to the inner tibial tuberosity and even as low as the upper margin of the popliteus; it communicates with the joint in 50 per cent. or more of cases (Foucher, Gruber); (*b*) a smaller bursa is found between the semimembranosus and the internal tuberosity of the tibia, communicating usually with the above-described bursa. Externally there are: (*c*) a bursa between the lateral ligament and the tendon of the popliteus; (*d*) a bursa—a diverticulum of the synovial membrane of the knee (Nancrede)—between the same tendon and the external tibial tuberosity; (*e*) a bursa between the external lateral ligament and the biceps tendon, in close relation to the external popliteal nerve; and (*f*) a bursa between the outer head of the gastrocnemius and the external condyle of the femur.

Nancrede says, that of the six popliteal bursæ, one—the subpopliteal (*d*)—always communicates with the joint, and occasionally with the upper tibio-fibular joint (Gruber); one—that between the gastrocnemius and the semimembranosus (*a*)—generally does so; and one (*c*) occasionally does so.

Enlargement of these bursæ leads to stiffness and disability in the use of the knee. Extension may be painful and may show the presence of a tense, rounded, fluctuating swelling. This will usually be at the inner side of the popliteal region, because the bursa beneath the gastrocnemius and semimembranosus—the largest of the bursæ—is the one most often enlarged.

It may, on account of the transmitted pulsation, be mistaken for an aneurism, but should be distinguished by the facts that, if due to bursal enlargement, the swelling—unlike that of aneurism—may (*a*) lessen or quite disappear when the knee is slightly flexed, the narrow passage between the bursal sac and the joint being compressed when the posterior ligament is tense and patulous when it is relaxed; (*b*) reappear slowly and not almost instantly; (*c*) become tenser and more prominent on full extension; (*d*) will have a transmitted, not an expansile pulsation; and (*e*) will be unaffected as to bulk by digital compression of the femoral artery.

A popliteal lipoma—the only other condition likely to be confused with a non-suppurating, enlarged bursa—occupies no definite position in the ham, has no sharply defined outline, undergoes little or no increase of tension when the leg is extended, and is apt to have attachments to the deep surface of the skin (Nancrede).

THE CRURAL MUSCLES.

The crural muscles are primarily inserted into the bones of the leg or into the tarsus, but, like the antibrachial muscles, many of them have been extended into the foot and act upon the digits.

The **crural fascia** is a strong aponeurotic sheath investing the muscles of the leg, at the knee being continuous with the fascia lata and below with the fascia of the foot. Over the external and internal malleoli and along the entire inner surface of the tibia the fascia blends with the subjacent periosteum; from the last of these attachments a deep layer is given off which passes across to the fibula, between the superficial and deeper muscles of the back of the leg. That portion of the fascia which covers the muscles of the front of the leg is exceedingly strong, but it is thinner over the calf. The upper part of its posterior portion is somewhat thickened, and forms part of the roof of the popliteal space. Below the fascia is strengthened by transverse fibres which form bands that bind down the tendons passing over the ankle-joint.

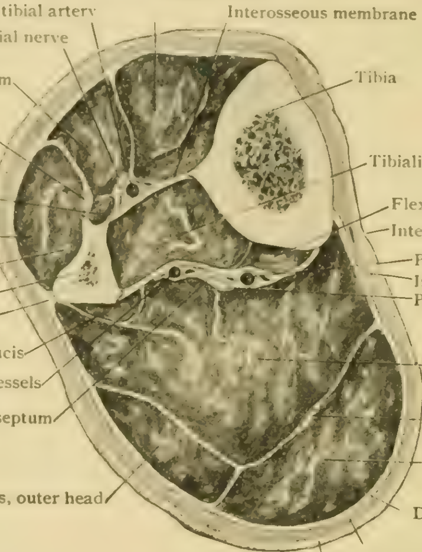
Of these bands two are situated upon the anterior surface of the ankle-joint, together forming the structure termed the *anterior annular ligament* (Fig. 623). The upper or *vertical portion* of this (**ligamentum transversum cruris**) extends transversely across between the lower ends of the tibia and fibula, a little above the ankle-joint. The space beneath this band is divided by a partition into two compartments, the more lateral of which contains the extensor longus hallucis and the extensor longus digitorum, enclosed by separate synovial sheaths, while the more medial one contains the tibialis anticus. The lower or *horizontal portion* of the ligament (**ligamentum cruciatum**) is Y-shaped. Externally it is attached to the outer surface of the calcaneum and passes inward, enclosing the tendons of the extensor longus digitorum, and then divides into two limbs, the upper of which passes upward and inward, over the tendons of the extensor longus hallucis and the tibialis anticus, to be inserted into the inner malleolus, just below the medial end of the ligamentum transversum. The lower limb passes downward and inward to be attached to the inner border of the plantar fascia.

On the posterior surface three bands occur. Two of these serve to bind down the tendons of the peroneus longus and brevis as they pass behind the external malleolus, together forming the *lateral annular ligament* (**retinacula mm. peronaeorum**). The upper band extends downward and backward from the outer malleolus to the calcaneum, while the lower one, arising from the calcaneum at the point at which the outer end of the cruciate ligament is attached, extends backward over the

peroneal tendons to be attached to the tuberosity of the same bone. The other band, the *internal annular ligament* (**ligamentum laciniatum**) passes downward and backward from the inner malleolus to the calcaneum, bridging over a groove which is divided into four compartments by partitions extending from the ligament to the subjacent bone. The innermost of these compartments is occupied by the posterior tibial muscle; the second one contains the tendon of the flexor longus digitorum; the third, the posterior tibial vessels and nerve; and the outermost, the tendon of the flexor longus hallucis.

From the deep surface of that portion of the crural fascia which covers the peroneus longus and brevis two strong expansions of connective tissue pass deeply,

FIG. 617.



Section across right leg at junction of upper and middle thirds, viewed from below.

one in front of and one behind the muscles, to be attached to the fibula. These are the *anterior* and *posterior intermuscular septa;* they serve for the origin of portions of the adjacent muscles.

In regions in which the crural fascia is adherent to subjacent bony structures a number of subcutaneous bursa occur between the deep fascia and the integument. Thus, over the patella there is usually to be found a bursa (**bursa prepatellaris subcutanea**); occasionally one (**bursa prepatellaris subfascialis**) occurs between the patella and the fascia. Another (**bursa infrapatellaris subcutanea**) frequently lies over the ligamentum patellæ, and immediately below it the **bursa subcutanea tuberositatis tibiae**. Again, over each malleolus a bursa often exists (**bursae malleoli lateralis et medialis**); finally, a bursa frequently occurs over the tendo Achillis at its insertion into the tuberosity of the calcaneum (**bursa subcutanea tendinis calcanei**).

(*a*) THE PRE-AXIAL MUSCLES.

As is the case with the antibrachial pre-axial muscles, those of the crus are primarily arranged in three layers, the most superficial sheet being attached above to the condyles of the femur, for the most part to the outer one. A further similarity to the arrangement in the forearm is to be found in the continuation of the muscles of the middle layer into the foot, to act as flexors of the digits.

(*aa*) The Superficial Layer.

1. Gastrocnemius. 2. Soleus.
3. Plantaris.

The main mass of the calf of the leg is formed by two muscles, the gastrocnemius and the soleus, which unite below in a common tendon, the *tendo Achillis* (**tendo calcaneus**), inserted into the posterior surface of the tuberosity of the calcaneum, a bursa (**bursa tendinis calcanei**) intervening between the tendon and the upper part of the tuberosity. Since the gastrocnemius arises by two heads, these two muscles together are sometimes spoken of as the *triceps suræ.*

Gastrocnemius (Fig. 618).

Attachments.—The gastrocnemius takes origin by two heads. The *outer head arises* from the posterior surface of the femur, just above the lateral condyle, by a short, strong tendon which sometimes contains a sesamoid cartilage ; the *inner* head *arises* also by a short tendon just above the medial condyle of the femur. Above, the two heads are separated from each other by a groove, but below they unite to form a thick belly, the fibres of which pass over into a broad, flat tendon *inserted* below with the tendo Achillis.

Nerve-Supply.—By the internal popliteal (tibial) division of the greater sciatic nerve from the first and second sacral nerves.

Action.—To extend the foot and to assist in flexing the knee-joint.

Relations.—The gastrocnemius is in relation by its posterior surface with the short saphenous vein and nerve. On its deep surface it is in contact with the plantaris and soleus muscles (Fig. 617), and in its upper part with the capsule of the knee-joint, the popliteus, and the popliteal vessels and nerves.

A bursa (**bursa m. gastrocnemii medialis**) intervenes between the inner head and the capsule of the knee-joint, with the synovial cavity of which it is frequently continuous; the **bursa m. gastrocnemii lateralis** frequently presents similar relations to the outer head.

Variations.—Absence of the entire muscle or of the outer head has been observed, but the most frequent anomaly is the occurrence of a third head which arises from some portion of the popliteal surface of the femur.

2. Soleus (Fig. 619).

Attachments.—The soleus is a broad, flat muscle which *arises* from the head and upper posterior portion of the fibula, from the oblique line of the tibia, and from a tendinous arch which passes across between the tibial and fibular origins. Its fibres pass downward to a broad tendon which joins with the tendo Achillis below.

Nerve-Supply.—By the internal popliteal (tibial) division of the greater sciatic nerve from the first and second sacral nerves.

Action.—To extend the foot.

3. Plantaris (Fig. 619).

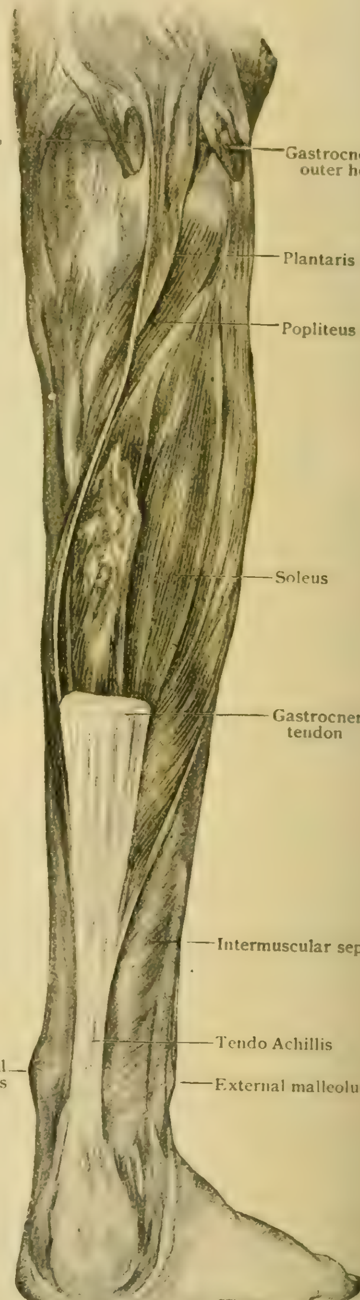
Attachments.—The plantaris is a small spindle-shaped muscle which passes over into a long, slender tendon extending downward between the gastrocnemius and soleus. The muscle *arises* from the femur, just above the outer condyle, internal to the lateral head of the gastrocnemius, and from the adjacent part of the posterior ligament of the knee-joint. The tendon traverses almost the entire length of the leg and is *inserted* either into the tuberosity of the calcaneum along with, but to the inner side of, the tendo Achillis, sending also some fibres to the internal annular ligament, or into the tendo Achillis itself.

Nerve-Supply.—By the internal popliteal (tibial) division of the greater sciatic nerve from the fifth lumbar and first sacral nerves.

FIG. 618.

Superficial dissection of posterior surface of right leg, showing muscles undisturbed.

FIG. 619.



Muscles of posterior surface of right leg; gastrocnemius has been removed, exposing plantaris and soleus.

Action.—To assist in extending the foot and to tense the crural fascia at the ankle-joint.

Variations.—The plantaris is absent in about 7 per cent. of cases. Its insertion may be into the calcaneum, the tendo Achillis, the crural fascia, or even into the plantar aponeurosis.

(*bb*) The Middle Layer.

1. Flexor longus digitorum. 2. Flexor longus hallucis.

1. Flexor Longus Digitorum (Figs. 620, 628).

Attachments.—The long flexor of the toes (**m. flexor digitorum longus**) *arises* from almost the whole of the posterior surface of the tibia below the oblique line and from the deep surface of the deep layer of the crural fascia. Its fibres converge in a bipinnate manner to a tendon which passes laterally to the tendon of the tibialis anticus beneath the internal annular ligament, and so reaches the plantar region of the foot. There it is directed somewhat laterally, receiving the insertion of the flexor accessorius, and divides into four tendons which, passing through the divided tendons of the flexor brevis, are *inserted* into the base of the third or distal phalanx of the second, third, fourth, and fifth toes.

Nerve-Supply.—By the posterior tibial nerve from the fifth lumbar and first sacral nerves.

Action.—To flex the second, third, fourth, and fifth toes ; continuing its action, to extend the foot and to cause slight inversion of the sole.

Relations.—In the leg (Fig. 617) the flexor longus is covered by the soleus and has resting upon it the lower portions of the posterior tibial vessels and nerve. It rests upon the tibialis posticus, crossing it obliquely in the lower part of the leg. In the foot its tendons are covered by the flexor brevis digitorum, and pass between the two terminal slips of the tendons of that muscle over the first phalanges. Its tendon is also covered by the abductor hallucis, and crosses obliquely the tendon of the flexor longus hallucis and the oblique portion of the adductor hallucis. The lumbricales take their origin from its tendons, and it receives the insertion of the flexor accessorius.

Variations.—A *flexor digitorum longus accessorius* is occasionally found arising independently from the tibia or from the fibula and joining the tendon of the long flexor below, or else uniting with the flexor accessorius.

2. Flexor Longus Hallucis (Figs. 620, 628).

Attachments.—The long flexor of the great toe (**m. flexor hallucis longus**) *arises* from the posterior surface of the fibula, from the posterior intermuscular septum, and from the deep surface of the deep layer of the crural fascia. Its fibres converge bipinnately to a tendon which passes beneath the internal annular ligament, posterior to the posterior tibial vessels and nerve, and so enters the plantar surface of the foot. There it passes beneath the tendon of the flexor longus digitorum, to which it sends a slip, and continues distally to be *inserted* into the base of the distal phalanx of the great toe, passing between the flexor brevis hallucis and the first plantar interosseous.

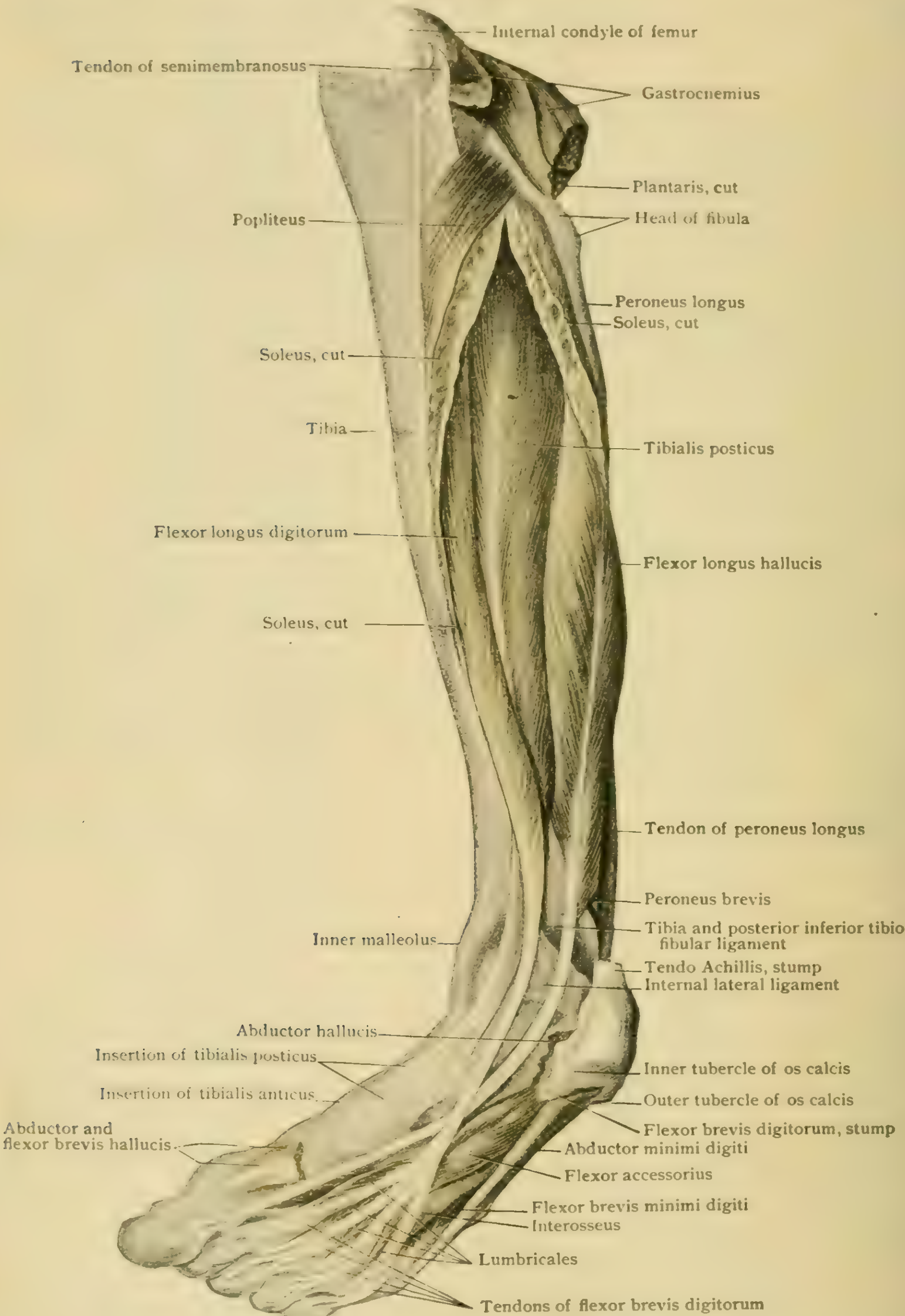
Nerve-Supply.—By the posterior tibial nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To flex the hallux and extend and slightly supinate the foot.

Variations.—The principal variations of the flexor longus hallucis concern its union with the tendon of the flexor longus digitorum. The passage of a slip between the two tendons is constant, but its distribution to the tendons of the flexor digitorum varies considerably. Usually it separates into two slips which pass to the tendons for the second and third toes, but it may also pass to the tendons for the second, third, and fourth toes, to that of the second alone, or even to all the tendons of the flexor longus digitorum. It may also completely replace the tendon usually passing from the flexor longus digitorum to the second digit.

These variations of the flexor longus hallucis are explicable on the basis that its history, together with that of the flexor longus digitorum, has been very similar to that of the flexor

FIG. 620.

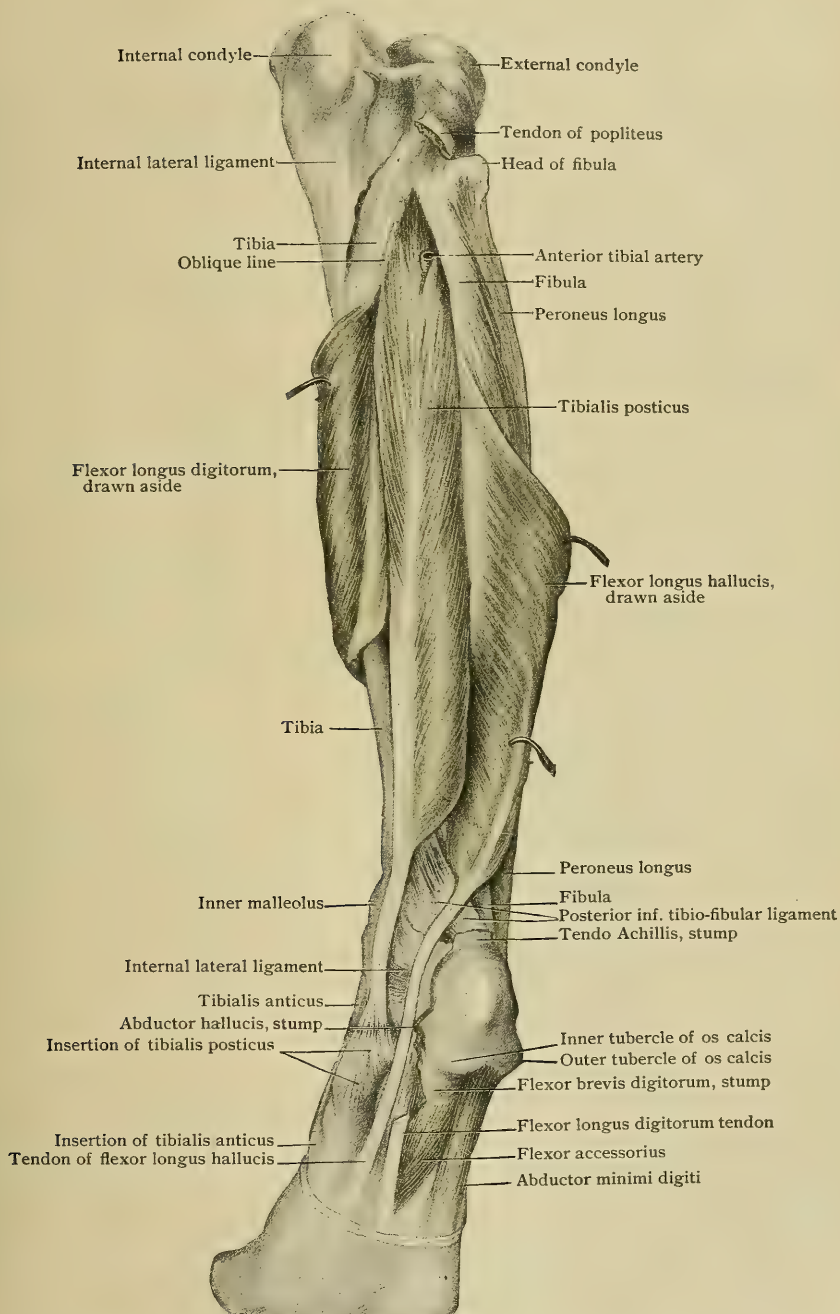


Deeper dissection of right leg, showing flexors passing into foot.

sublimis digitorum and flexor longus pollicis of the forearm. In other words, these muscles represent a layer of muscle-tissue which primarily arose from the bones of the leg and was inserted into the deeper layers of the plantar aponeurosis. Later tendons differentiated from the

plantar aponeurosis and the muscles were continued to the digits. The separation of the flexor hallucis from the rest of the muscle took place later, and even yet is somewhat incomplete, the

FIG. 621.



Deep dissection of right leg; flexors have been turned aside to expose tibialis posticus.

connections between its tendon and that of the flexor longus digitorum being indications of its developmental history.

(*cc*) The Deep Layer.

1. Tibialis posticus. 2. Flexor accessorius.
3. Popliteus.

1. Tibialis Posticus (Fig. 621).

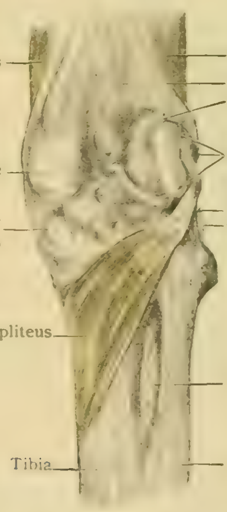
Attachments.—The posterior tibial (**m. tibialis posterior**) *arises* from the posterior surface of the interosseous membrane and from the adjacent surface of both the tibia and fibula. Its fibres pass into a tendon, situated along its inner border, which passes obliquely downward and inward beneath the flexor longus digitorum. It is continued onward beneath the most central portion of the internal annular ligament to the plantar surface of the foot, where it is *inserted* into the tuberosity of the scaphoid bone, sending prolongations to all the other tarsal bones, except the astragalus, and to the bases of the second, third, and fourth metatarsals.

Nerve-Supply.—By the posterior tibial nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To extend the foot and to slightly invert the sole.

Relations.—The posterior tibial is the deepest muscle upon the posterior surface of the leg. It is covered by the soleus and by the flexor longus digitorum, and has resting upon it the upper portion of the posterior tibial and peroneal vessels (Fig. 617). The anterior tibial vessels pass through the interosseous membrane immediately above the origin of the muscle. A bursa sometimes intervenes between its tendon and the tuberosity of the scaphoid bone, and the tendon usually contains a sesamoid cartilage or bone where it passes over the head of the astragalus.

Fig. 622.



Deep dissection of leg, showing popliteus muscle.

Variations.—A portion of the muscle is sometimes inserted into the internal annular ligament.

A muscle, which has been called the *peroneo-tibialis*, not infrequently extends across between the fibula and tibia, immediately beneath the tibio-fibular articulation and above the anterior tibial vessels as they pass towards the front of the leg. It is usually rudimentary, but may form a well-marked triangular sheet.

2. Flexor Accessorius (Fig. 628).

Attachments.—The accessory flexor of the toes (**m. quadratus plantae**) *arises* by two heads from the medial and inferior surfaces of the calcaneum and, passing distally, is *inserted* into the tendon of the flexor longus digitorum.

Nerve-Supply.—By the external plantar nerve from the first and second sacral nerves.

Action.—By acting on the long flexor tendons, to flex the second, third, fourth, and fifth toes, and to counteract the oblique pull of the long flexor.

The flexor accessorius, although apparently located entirely in the foot, is, nevertheless, a crural muscle, since the tendon of the flexor longus digitorum, into which it is inserted, represents, as has already been pointed out, a portion of the plantar aponeurosis. Into this many of the muscles of the leg were primarily inserted, and the accessorius represents the most distal portion of the original deep sheet of the crural musculature.

3. Popliteus (Fig. 622).

Attachments.—The popliteus *arises* by a narrow tendon from the outer condyle of the femur and by a slip from the posterior ligament of the knee-joint. It passes inward and downward to be *inserted* into the posterior surface of the tibia above the oblique line.

Nerve-Supply.—By the internal popliteal (tibial) division of the greater sciatic nerve from the fifth lumbar and first sacral nerves.

Action.—To flex the leg and rotate it inward.

Relations.—On its posterior surface it is covered by the plantaris and gastrocnemius, and it is crossed by the popliteal vessels and internal popliteal nerve. By its deep surface it is in relation to the capsule of the knee-joint, a bursa (**bursa m. poplitei**) intervening.

Variations.—The most frequent anomaly in connection with the popliteus is the occurrence of a second head, which arises from the sesamoid cartilage of the lateral head of the gastrocnemius. The occurrence of this head is frequently associated with the absence of the plantaris.

(*b*) THE POST-AXIAL MUSCLES.

1. Tibialis anticus.
2. Extensor longus digitorum.
3. Peroneus tertius.
4. Extensor longus hallucis.
5. Peroneus longus.
6. Peroneus brevis.

Tibialis Anticus (Fig. 623).

Attachments.—The anterior tibial muscle (**m. tibialis anterior**) *arises* from the outer tuberosity and surface of the tibia and also from the interosseous membrane and the crural fascia. Its fibres extend downward to a strong tendon which passes through the inner compartment of the anterior annular ligament and is *inserted* into the inner surface of the internal cuneiform and the base of the first metatarsal bone.

Nerve-Supply.—By the anterior tibial nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To flex the foot; to draw up the inner border and hence invert the sole.

Relations.—The anterior tibial rests upon the lateral surface of the tibia and upon the interosseous membrane, and is in contact externally with the extensor longus digitorum, the extensor longus hallucis, and the anterior tibial vessels and nerve (Fig. 617). A bursa (**bursa subtendinea m. tibialis anterioris**) intervenes between its tendon and the medial cuneiform bone.

Variations.—Not infrequently a bundle is detached from the muscle to be inserted into the anterior annular ligament, into the dorsal fascia of the foot, or, in some cases, into the astragalus. It forms what has been termed the *tibio-fascialis anterior* or *tibio-astragalus*.

2. Extensor Longus Digitorum (Fig. 623).

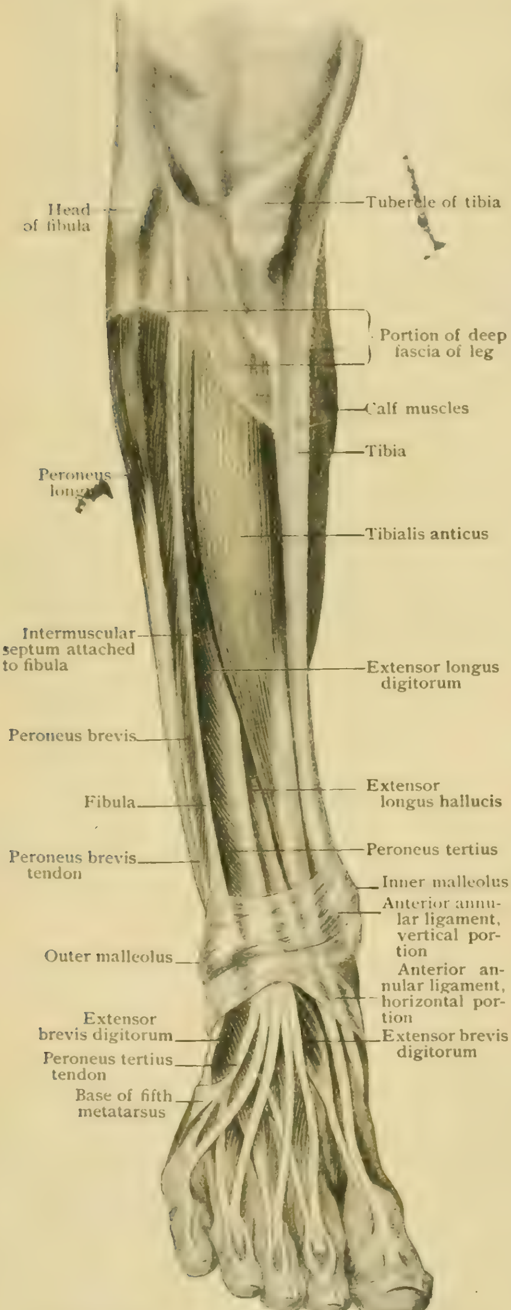
Attachments.—The long extensor of the toes (**m. extensor digitorum longus**) *arises* from the external condyle of the tibia, the upper part of the fibula, the interosseous membrane, the intermuscular septum, and the crural fascia. Its fibres pass downward and terminate at about the middle of the leg in a tendon which passes through the outer compartment of the anterior annular ligament and divides into four tendons which pass to the second, third, fourth, and fifth toes. Over the metatarso-phalangeal joint of its digit each tendon spreads out into a membranous expansion which covers the dorsum of the first phalanx and receives the insertions of the interossei and lumbricales, and, in the case of the second, third, and fourth toes, those of the extensor brevis digitorum. Distally each membranous expansion divides into three slips, of which the middle one is *inserted* into the second phalanx and the lateral ones into the third phalanx of its digit.

Nerve-Supply.—From the anterior tibial nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To extend the second, third, fourth, and fifth toes and to flex the foot.

Relations.—By its deep surface and medially the muscle is in relation with the extensor longus hallucis, medially with the tibialis anticus, the anterior tibial vessels and nerve, and deeply with the deep peroneal nerve above and the ankle-joint below. Laterally it is in contact with the peroneus longus above, with the peroneus tertius below, and with the musculo-cutaneous nerve, which passes downward between it and the peroneus longus (Fig. 617).

FIG. 623.



Superficial dissection of anterior surface of right leg, showing muscles undisturbed.

Variations.—Considerable variation occurs in the arrangement of the terminal tendons, one of the most usual departures from the typical condition being a duplication of the tendon to one or more of the toes, the additional tendon either passing to the same digit as its fellow or to an adjacent one. Occasionally a slip passes from the innermost tendon to that of the extensor longus hallucis, and slips may pass from any of the tendons to the metatarsal bones.

3. Peroneus Tertius (Fig. 623).

Attachments.—The peroneus tertius *arises* from the lower part of the anterior surface of the fibula and from the interosseous membrane, the intermuscular septum, and the crural fascia. At about the level of the ankle its fibres pass over into a tendon which continues through the lateral compartment of the anterior annular ligament, together with the tendon of the extensor longus digitorum, and is *inserted* into the base of the fifth metatarsal bone.

Nerve-Supply.—By the anterior tibial nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To flex and evert the foot.

Variations.—The peroneus tertius is quite frequently absent, and is usually more or less closely united with the extensor longus digitorum above. Its tendon sometimes splits into two portions, the additional one passing either to the fifth toe or to the fourth metatarsal.

Notwithstanding its name, which has reference to its origin from the fibula, the peroneus tertius has morphologically nothing to do with the other peroneal muscles, but is a separated portion of the extensor longus digitorum, whose connections with the metatarsals are interesting in this regard.

4. Extensor Longus Hallucis (Fig. 624).

Attachments.—The long or proper extensor of the great toe (**m. extensor hallucis longus**) *arises* from the inner surface of the fibula and from the interosseous membrane.

Its fibres are collected into a tendon which passes through the middle compartment of the anterior annular ligament and is continued distally to the great toe. Over the metatarso-phalangeal joint it spreads out into a membranous expansion which receives a tendon of the extensor brevis digitorum and is then continued distally to be *inserted* into the first and second phalanges.

Nerve-Supply.— By the anterior tibial nerve from the fourth and fifth lumbar and first sacral nerves.

Action. — To extend the great toe and flex the foot.

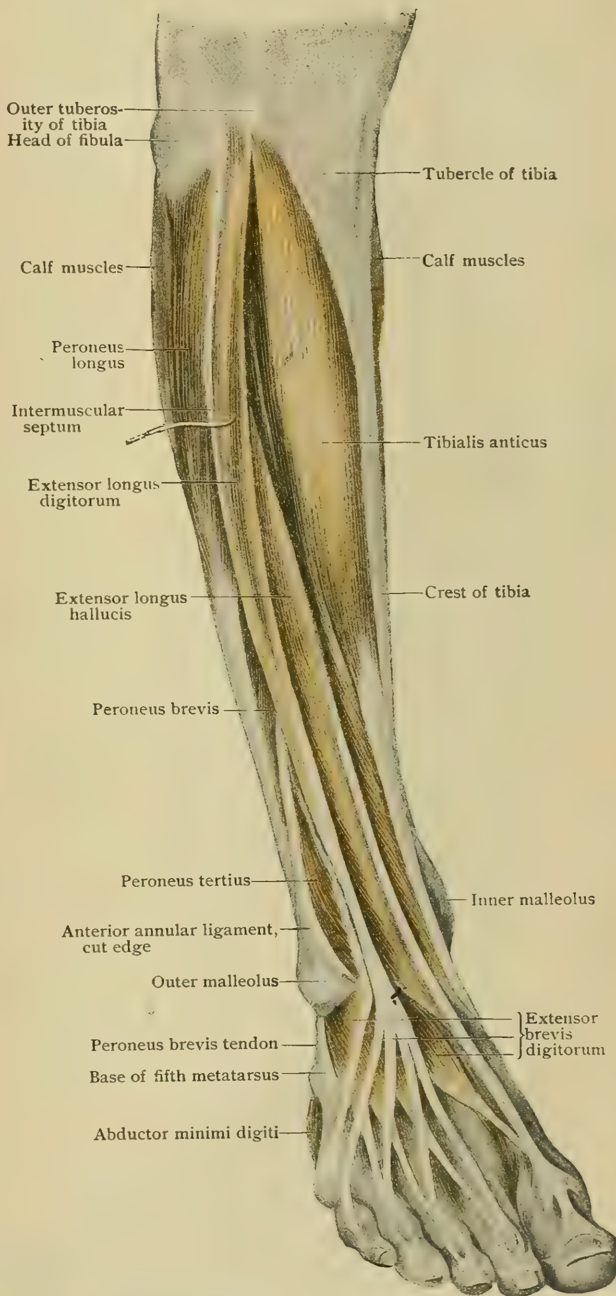
Relations.—The extensor longus hallucis is covered in its upper part by the tibialis anticus and the extensor longus digitorum. Near the ankle it crosses obliquely over the anterior tibial artery and passes upon the foot between the tendons of the extensor longus digitorum and the tibialis anticus, internal to the arteria dorsalis pedis.

Variations.—The muscle is occasionally united at its origin with the extensor longus digitorum, and, in addition to the connections which may exist between its tendon and that of the long extensor, it may also be connected with one of the tendons of the extensor brevis digitorum.

A small muscle is sometimes to be found passing downward alongside of the extensor brevis hallucis to be inserted into the base of the first metatarsal. It may be termed the *abductor longus hallucis*, and takes its origin either from the fibula close to the origin of the extensor longus hallucis, or from that muscle, or from the extensor longus digitorum or the tibialis anticus.

What has been termed an *extensor brevis hallucis* is frequently represented by a slip from the extensor longus hallucis, the extensor longus digitorum, or even from the tibialis anticus inserting into the base of the first phalanx of the hallux.

FIG. 624.



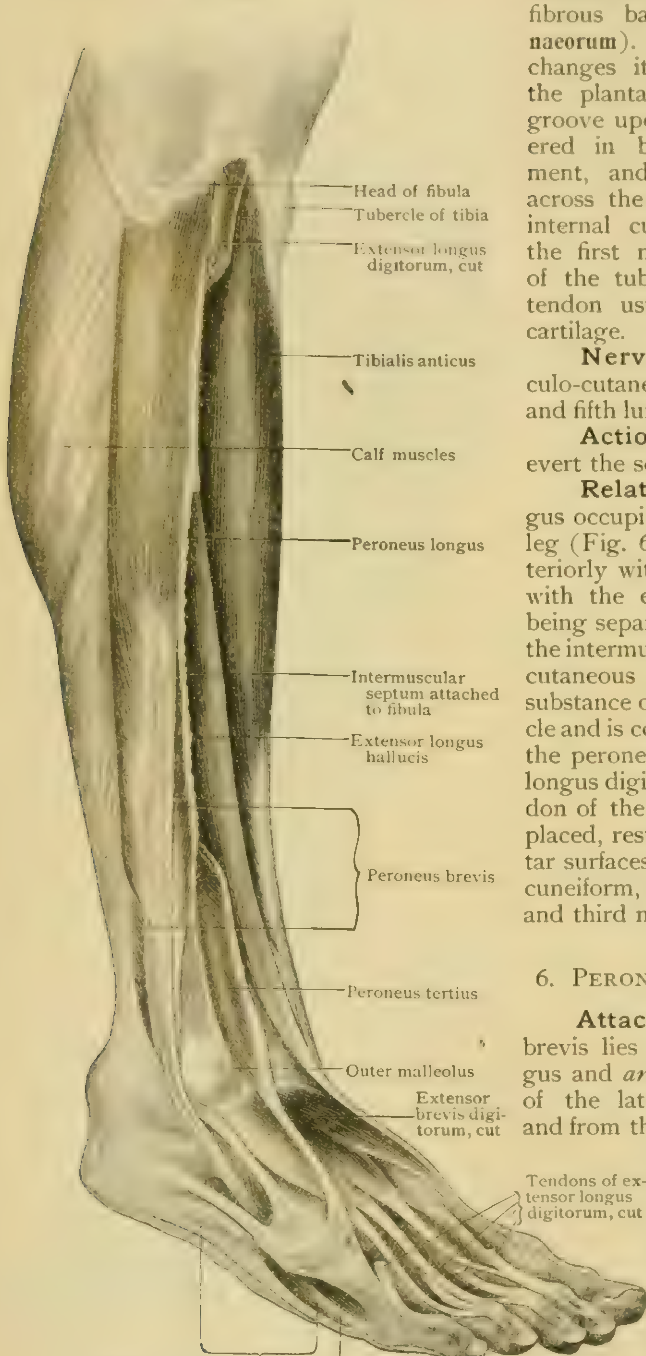
Muscles of anterior surface of right leg; extensor longus digitorum has been drawn aside to expose extensor longus hallucis.

5. Peroneus Longus (Figs. 625, 629).

Attachments.—The peroneus longus *arises* from the upper part of the lateral surface of the fibula and from the intermuscular septa and crural fascia. Its fibres

extend obliquely downward to a tendon which passes behind the outer malleolus and then runs forward in a groove on the calcaneum, in which it is held by fibrous bands (**retinacula mm. peronaeorum**). On the cuboid it again changes its direction, passing upon the plantar surface of the foot in a groove upon that bone which is covered in by the long plantar ligament, and then, running obliquely across the foot, it is *inserted* into the internal cuneiform and the base of the first metatarsal bone. In front of the tuberosity of the cuboid the tendon usually contains a sesamoid cartilage.

FIG. 625.



Superficial dissection of right leg, antero-lateral aspect, showing peroneal muscles.

Nerve-Supply.—By the musculo-cutaneous nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To extend the foot and evert the sole.

Relations.—The peroneus longus occupies the lateral surface of the leg (Fig. 617). It is in contact posteriorly with the soleus and internally with the extensor longus digitorum, being separated from these muscles by the intermuscular septa. The musculo-cutaneous nerve passes through the substance of the upper part of the muscle and is continued downward between the peroneus longus and the extensor longus digitorum. In the foot the tendon of the peroneus longus is deeply placed, resting directly upon the plantar surfaces of the cuboid, the external cuneiform, and the bases of the second and third metatarsal bones.

6. PERONEUS BREVIS (Fig. 624).

Attachments.—The peroneus brevis lies beneath the peroneus longus and *arises* from the lower portion of the lateral surface of the fibula and from the intermuscular septa. Its fibres join a tendon which passes behind the external malleolus and then distally, along with the tendon of the peroneus longus, beneath the fibrous bands or retinacula to be *inserted* into the tuberosity of the fifth metatarsal bone.

Nerve-Supply.—By the musculo-cutaneous nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To extend and evert the foot.

Variations.—A slip is very frequently given off from the tendon of the short peroneus which is inserted either into the tendon of the extensor longus digitorum passing to the fifth toe or directly into that digit. In some cases the slip arises from the belly of the muscle, from that of the peroneus longus, or even from the fibula directly, and represents what has been termed the *peroneus quintus*.

A *peroneus quartus*, where distinctness from the quintus seems doubtful, sometimes occurs as a muscle arising from the lower part of the fibula and inserting into the calcaneum or the tuberosity of the cuboid.

THE MUSCLES OF THE FOOT.

The **plantar fascia** or **aponeurosis** (Fig. 626) is a dense sheet of connective tissue lying immediately beneath the skin of the plantar surface of the foot and covering the pre-axial muscles. It is attached behind to the tuberosity of the calcaneum, and extends distally in a fan-like manner to be attached by five processes to the skin over the metatarso-phalangeal joints of the digits. The aponeurosis is much thicker in its middle portion than at the sides, where it is continued dorsally over the sides of the foot to become continuous with the fascia of the dorsum of the foot and with the crural fascia. Between its cutaneous insertions transverse bands of fibres stretch across to form the *superficial transverse metatarsal ligament* (**fasciculi transversi**); from its deep surface strong sheets are given off which pass to the sheaths of the flexor tendons. Expansions are also given off from its deep surface which invest the flexor brevis digitorum and, on either side, the abductor hallucis and abductor minimi digiti.

FIG. 626.

Superficial dissection of sole of right foot (subject lying on belly), showing plantar fascia.

Between the aponeurosis and the integument over the inferior surface of the tuberosity of the calcaneum a bursa (**bursa subcutanea calcanea**) is constantly present.

The dorsal surface of the foot is covered by the **fascia dorsalis pedis**, a rather thin sheet continuous with the crural fascia above. It covers the long extensor tendons.

(*a*) THE PRE-AXIAL MUSCLES.

Like the pre-axial muscles of the hand, those of the foot may be regarded as derived from five primary layers, which have undergone a considerable amount of modification, including some fusion.

(*aa*) The Muscles of the First Layer.

1. Flexor brevis digitorum.
2. Flexor brevis hallucis.
3. Abductor hallucis.
4. Abductor minimi digiti.

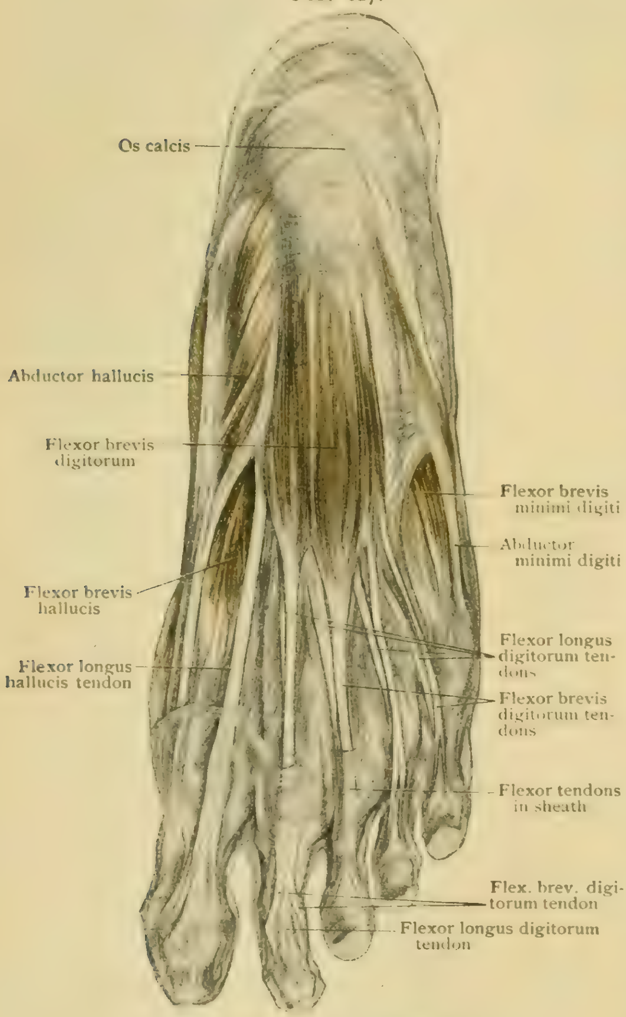
1. Flexor Brevis Digitorum (Fig. 627).

Attachments.—The short flexor of the toes (**m. flexor digitorum brevis**) *arises* from the inner process of the calcaneal tuberosity and from the plantar aponeurosis. It extends distally, beneath the aponeurosis, as a thick quadrangular muscle, the fibres of which are collected over the metatarsal bones into four tendons which pass to the second, third, fourth, and fifth toes. Over the first phalanx of the toe each tendon divides into two terminal slips, between which the corresponding tendon of the flexor longus digitorum passes and which are *inserted* into the second phalanx.

Nerve-Supply.— By the internal plantar nerve from the fourth (and fifth lumbar and first sacral nerves.

Action.—To flex the second, third, fourth, and fifth toes.

Fig. 627.



Superficial muscles of sole of right foot.

Variations.—The most frequent variation in this muscle is the absence of the tendon to the fifth toe, an absence which occurs in somewhat over 21 per cent. of cases examined. Sometimes the tendon is replaced by a slip or muscle which arises from the tendon of the flexor longus digitorum.

The flexor brevis represents the middle portion of the superficial flexor layer, and corresponds, accordingly, to the terminal portions of the tendons of the flexor sublimis of the hand. Its origin is primarily from the plantar aponeurosis, and hence the occasional origin of the portion for the fifth toe becomes intelligible, since the tendon of the flexor longus is a differentiation of the deeper layer of the aponeurosis.

2. Flexor Brevis Hallucis (Fig. 628).

Attachments.—The short flexor of the great toe (**m. flexor hallucis brevis**) *arises* from the plantar surface of the internal cuneiform bone and the adjacent ligamentous structures. Its fibres pass distally to a tendon which contains a sesamoid bone, and is *inserted* into the inner surface of the base of the first phalanx of the great toe.

Nerve-Supply.—By the internal plantar nerve from the fourth lumbar nerve.

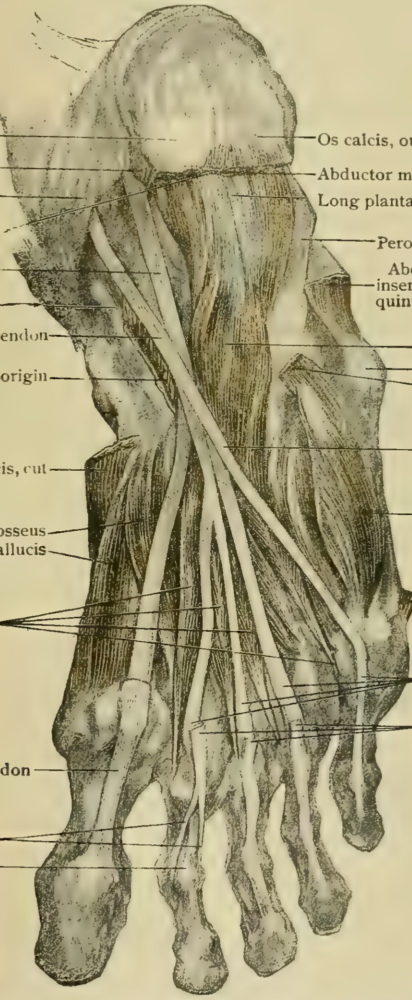
Action.—To flex the great toe.

Variations.—The flexor brevis hallucis is frequently intimately fused with the abductor hallucis.

A portion of the deeper fibres of the flexor brevis hallucis is frequently inserted into the whole length of the first metatarsal. Occasionally these fibres are quite distinct from the rest of the muscle, forming what has been termed an *opponens hallucis*.

In the description of the muscle given above, account has been taken only of what is usually described as the inner portion, the flexor brevis pollicis being usually regarded as consisting of two bellies, the second of which is inserted into the lateral side of the base of the first phalanx of the great toe. The relations of this outer belly and its nerve-supply, however, indicate that it belongs to an entirely different layer than the medial belly. It will, therefore, be considered later in connection with the interossei (page 663).

FIG. 628.



Long and accessory flexors of right sole, exposed by removal of superficial muscles.

3. ABDUCTOR HALLUCIS (Fig. 627).

Attachments.—The abductor hallucis extends along the inner border of the foot, *arising* from the inner tubercle and surface of the calcaneum and from the plantar aponeurosis and being *inserted*, along with the flexor brevis hallucis, into the inner side of the base of the first phalanx of the great toe.

Nerve-Supply.—By the internal plantar nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To abduct and flex the hallux.

Abductor Minimi Digiti (Fig. 627).

Attachments.—The abductor of the little toe (**m. abductor digiti quinti**) is situated along the outer border of the foot. It *arises* from the under surface of the calcaneum and from the plantar aponeurosis, and extends distally and laterally to be *inserted* partly into the tuberosity of the fifth metatarsal bone and partly into the lateral side of the base of the first phalanx of the little toe.

Nerve-Supply.—By the external plantar nerve from the first and second sacral nerves.

Action.—To abduct and flex the little toe.

Variations.—A portion of the abductor digiti quinti frequently separates from the rest of the muscle to form a fusiform belly which has been termed the *abductor ossis metatarsi quinti*. It arises from the lateral part of the inferior surface of the os calcis and is inserted, either independently or in common with the abductor, into the tuberosity of the fifth metatarsal.

(*bb*) The Muscles of the Second Layer.

1. Lumbricales (Fig. 628).

Attachments.—The lumbricales are four spindle-shaped muscles which *arise* from the adjacent borders of the tendons of the flexor longus digitorum and from the inner border of its first tendon. They pass distally to the inner surfaces of the first phalanges of the second, third, fourth, and fifth digits, where they are *inserted* into the membranous expansions of the tendons of the extensor longus digitorum.

Nerve-Supply.—The first or first and second muscles, counting from the tibial side, are supplied by the internal plantar nerve ; the remaining three or two are supplied from the external plantar from the fourth and fifth lumbar and first sacral nerves.

Action.—To flex and draw medially the second, third, fourth, and fifth toes.

Variations.—Absence of one or other of the lumbricales has been noted, the fourth and third being those most frequently lacking ; these same muscles are frequently bifid at their insertions. Small bursæ may intervene between the tendons and the first phalanges.

The significance of the lumbricales is similar to that of the corresponding muscles of the hand. They arise primarily from the deeper layers of the plantar aponeurosis, and when these differentiate into the tendons of the flexor longus digitorum they come to arise from those structures.

(*cc*) The Muscles of the Third Layer.

1. Adductor Hallucis (Fig. 629).

Attachments.—The adductor hallucis consists of two portions, often described as two distinct muscles, united only at their insertions. The *oblique portion* (**caput obliquum**), or *adductor obliquus*, *arises* from the bases of the second, third, and fourth metatarsals and from the long plantar ligament and passes distally and inward along the interval between the first and second metatarsals, its fibres converging to a strong tendon which unites with that of the *transverse portion* (**caput transversum**), or *adductor transversus*. This extends almost transversely, under cover of the three medial tendons of the long and short flexors and the lumbricales, over the heads of the fourth, third, and second metatarsals. It *arises* from the capsules of the four lateral metatarso-phalangeal joints and passes medially to join the tendon of the oblique portion. The common tendon so formed unites with the tendon of the first plantar interosseous and is *inserted* into the sesamoid bone of that tendon and into the lateral surface of the base of the first phalanx of the great toe.

Nerve-Supply.—By the deep branch of the external plantar nerve from the fifth lumbar and first and second sacral nerves.

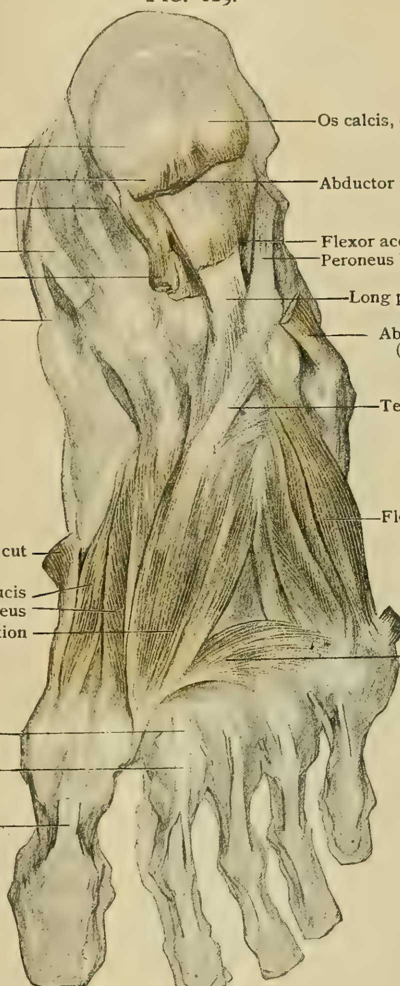
Action.—To flex and adduct the hallux.

Variations.—Some variation occurs in the extent of the origin of both portions of the adductor hallucis. The oblique portion may be limited to the long plantar ligament, or may receive an accessory slip from the shaft of the second metatarsal, while the origin of the transverse portion from the fifth metatarso-phalangeal joint may be lacking.

It is to be noted that in the fœtus the two portions of the adductor are not separated by a wide interval as in the adult, but lie in contact with each other.

A small muscular slip has occasionally been observed passing from the long plantar ligament to the lateral surface of the base of the first phalanx of the second toe. It appears to represent an *adductor secundi digiti.*

FIG. 629.



Deep dissection of sole of right foot, showing short flexors of great and little toes and adductor muscles.

(*dd*) THE MUSCLES OF THE FOURTH AND FIFTH LAYERS.

1. Interossei plantares. 2. Interossei dorsales.
3. Flexor brevis minimi digiti.

As in the hand, the fourth and fifth layers of the pre-axial musculature become united to form the *dorsal interossei*, portions of the fourth layer remaining distinct to form the *plantar interossei.* The arrangements in the hand and foot differ, however, in this respect, that in the foot the lateral muscle derived from the fourth layer forms a large, well-developed structure termed the flexor brevis minimi digiti.

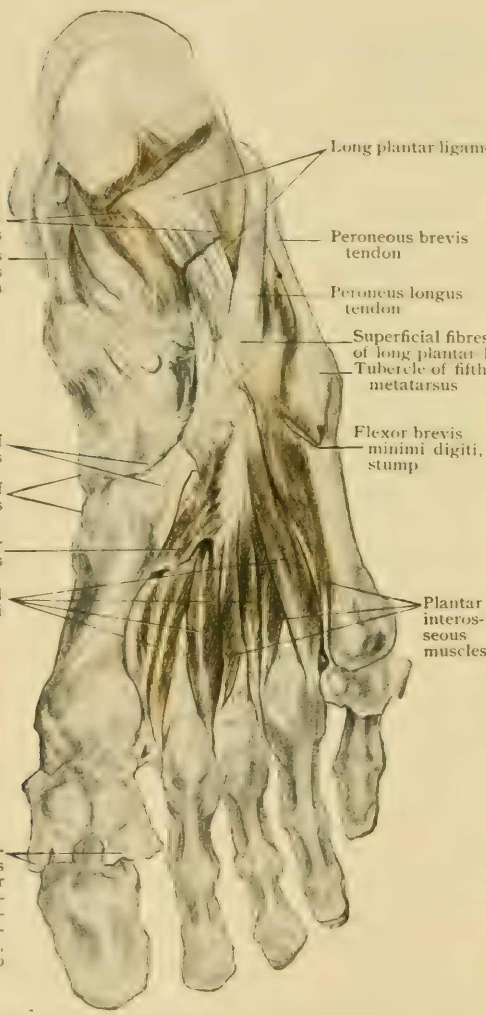
1. INTEROSSEI PLANTARES (Fig. 630).

Attachments.—The plantar interossei are four spindle-shaped muscles. The first is very much stronger than the others, and is often described as the outer head of the flexor brevis hallucis (page 661). It *arises*, in common with the flexor brevis

hallucis, from the inner cuneiform bones and the adjacent ligamentous structures. It extends distally along the lateral surface of the first metatarsal bone and passes over into a strong tendon, which contains a sesamoid bone, and is *inserted* into the outer surface of the base of the first phalanx of the great toe, along with the adductor hallucis.

The remaining three muscles are much smaller and *arise* in succession from the medial surfaces of the third, fourth, and fifth metatarsals, and, passing distally, are *inserted* by slender tendons into the membranous expansions of the long extensor tendons of the third, fourth, and fifth toes, on the medial sides of their first phalanges.

FIG. 630.



Deep dissection of sole of right foot, showing interosseous muscles.

Nerve-Supply.—By the external plantar nerve from the first and second sacral nerves.

Action.—To flex the first, third, fourth, and fifth toes and to draw the last three medially.

Variations.—As above stated, the first plantar interosseus is usually described as a second head of the flexor brevis hallucis. It is sometimes more or less inseparable from the oblique portion of the adductor hallucis.

2. INTEROSSEI DORSALES (Figs. 623, 630).

Attachments.—The dorsal interossei are also four in number. They *arise* from the adjacent sides of each pair of metatarsals and pass distally in the interspaces between these bones. The fibres of each muscle converge to a narrow tendon which is *inserted* into the membranous expansions of the extensor tendons over the first phalanges of the second, third, and fourth toes. The first and second muscles insert into the opposite sides of the second toe and the third and fourth into the lateral sides of the third and fourth toes.

Nerve-Supply.—By the external plantar nerve from the first and second sacral nerves.

Action.—To flex the second, third, and fourth toes; the first also draws the second toe medially and the rest the second, third, and fourth toes laterally.

3. FLEXOR BREVIS MINIMI DIGITI (Fig. 629).

Attachments.—The short flexor of the little toe (**m. flexor digiti quinti brevis**), which really represents a fifth plantar interosseus, *arises* from the base of the fifth

metatarsal and passes distally along the outer side of the fourth plantar interosseus to be *inserted* by a tendon into the outer surface of the base of the first phalanx of the fifth toe and also into the distal portion of the fifth metatarsal.

Nerve-Supply.—From the external plantar nerve from the second sacral nerve.

Action.—To flex the fifth toe and draw it lateralward.

Variations.—The portion of the flexor brevis minimi digiti which passes to the fifth metatarsal is frequently more or less distinct from the rest of the muscle, and has then been termed the *opponens quinti digiti.*

(*b*) THE POST-AXIAL MUSCLES.

I. EXTENSOR BREVIS DIGITORUM (Fig. 624).

Attachments.—The short extensor of the toes (**m. extensor digitorum brevis**) *arises* from the lateral and superior surfaces of the calcaneum. It passes distally beneath the tendons of the extensor longus digitorum and divides into four portions, the outer three of which soon become tendinous and are *inserted* by fusing with the tendons of the extensor longus to the second, third, and fourth toes over the first phalanges of those toes; the innermost tendon is inserted into the base of the first phalanx of the great toe.

Nerve-Supply.—By the anterior tibial nerve from the fourth and fifth lumbar and first sacral nerves.

Action.—To extend and draw laterally the first, second, third, and fourth toes.

Variations.—Occasionally one or other of the tendons of the extensor brevis may be doubled, this condition being most frequent in the tendon to the second toe; sometimes a fifth tendon passes to the little toe.

The innermost tendon is nearly always much stronger than the others; the fibres which insert into it are occasionally separate from the remainder of the muscle, then forming the *extensor brevis hallucis.*

PRACTICAL CONSIDERATIONS: MUSCLES AND FASCIÆ OF THE LEG, ANKLE, AND FOOT.

1. **The Leg.**—The skin over the leg is everywhere more adherent to the underlying fascia than it is in the thigh. Its inability at certain places, as over the spine and antero-internal surface of the tibia, to glide away when force is applied partly accounts for the frequency with which bruising or laceration, superficial ulceration, or even periostitis or caries follows injuries to the "shin."

The deep fascia blends with the periosteum at the head and inner and anterior borders of the tibia, at the head of the fibula, and at the two malleoli. It is thicker and denser above and anteriorly than below and posteriorly. The two septa (Figs. 627, 623) that run inward from it on the outer side of the leg and are attached to the anterior and external borders of the fibula constitute an osseo-aponeurotic space that contains the peroneal muscles and that may, for a time, limit the spread of infection or of suppuration. The peronei, in their compartment, and, farther in, the bones and interosseous membrane, separate the anterior group of muscles—the tibialis anticus, extensor communis, etc.—from the posterior group. The fascia over the anterior group embraces them so closely, that when it is wounded or torn the muscle-fibres protrude and approximation of the edges of the fascial wound may be difficult. In the anterior compartment the muscles are intimately adherent to its fibrous walls, as is the case in the forearm, but not in the arm or thigh (Tillaux). In the posterior compartment, on the contrary, a loose layer of connective tissue intervenes between the gastrocnemius and the deep fascia, and permits the greater degree of motion between the muscle and the aponeurosis necessitated by the greater range of motion in plantar, as compared with dorsal, flexion of the foot.

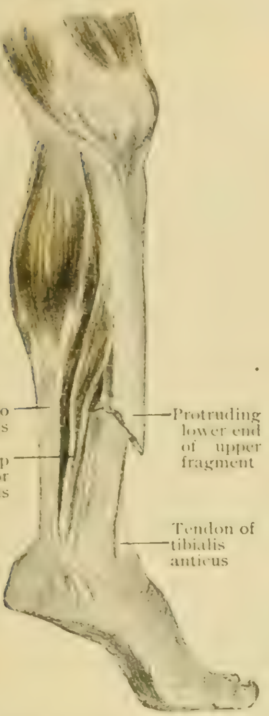
The difference will be noted in dealing with wounds involving these regions, or in some operations, as amputation of the leg.

The septum, anteriorly, at the upper third of the leg, between the tibialis anticus and extensor longus digitorum, is of variable density, gives no indication of its pres-

ence on either the skin or fascial surface, and although described as a guide to the anterior tibial artery (*q.v.*), is untrustworthy on account of the difficulty of recognizing it (Treves).

Posteriorly the deep layer of fascia that holds down the deep muscles to the tibia and fibula and runs transversely beneath the soleus and gastrocnemius, is weaker above, where it is covered and reinforced by the latter muscles, and stronger below, where it loses their support. It is continued downward and separates the tendo Achillis from the deeper structures. In approaching the vessels behind the malleolus, one finds, therefore, two layers of deep fascia.

Fig. 631.



Dissection of fracture of left tibia, showing effect of muscular action on fragments.

Growths originating in the head of the tibia or occupying the interosseous space are much influenced by the resistance of the deep fascia, which, as is the case with the fascia lata, may for a time determine their shape and direction and alter their surface appearance and their apparent density.

Cellulitis and abscess are for a while confined beneath the fascia, but, like the coloring matter of the blood after fracture, may soon find their way to the surface by following the vessels that perforate it.

Some fibres of the gastrocnemius or, more frequently, the tendo Achillis at its weakest point, on a level with the internal malleolus, may be ruptured during strong effort, as in raising the body on the toes while bearing a weight. Sometimes, however, this accident follows comparatively trifling exertion.

2. **The Ankle and Foot.**—The skin around the ankle and upon the dorsum of the foot is thin and lax. The absence of a fatty or muscular layer between it and the subjacent bones and the distance of the region from the centre of circulation make gangrene from relatively slight contusion, or from the pressure of splints or dressings, more common here than elsewhere.

Over the sole, especially at those places which normally bear the weight of the body,—the heel, the ball of the great toe, the line of the heads of the metatarsal bones (page 452), and the outer side of the foot,—the skin is much denser. It often contains callosities which cause pain by pressure and are usually the result of friction between the sole and an ill-fitting shoe. Its close connection with the underlying plantar fascia is similar to that between the skin of the palm and the palmar fascia, and between the skin of the scalp and the occipito-frontalis aponeurosis, in all of which regions the integument is exceptionally thick and dense, and in the former two hairless (page 491). Under the heel the thick skin and the pad of subcutaneous fascia containing fat are especially valuable in lessening the force of falls upon that part of the foot, where there is no elastic arch composed of a number of bones and joints to take up and distribute the force, as do both the transverse arch and the anterior pillar of the main arch (page 436). This tissue, vertical and scanty in the sole, is loose and abundant on the dorsum and around the tendo Achillis, in which latter region it contains some fat. Its laxity over the dorsum, while it somewhat protects the instep from the effects of direct violence, adds greatly to the ease with which swelling or œdema may occur in cellulitis or, on account of the dependent position of the part and its remoteness from the heart, in anasarca.

The deep fascia at the ankle is thickened on the dorsum and sides to form the annular ligaments, the chief function of which is to hold in place the tendons that move the foot and toes. Anteriorly this is done by two bands, beneath the upper of which the tendon of the tibialis anticus runs, while the lower covers in the tendon of the same muscle and those of the extensor proprius pollicis and of the extensor com-

munis and peroneus tertius, the last two running in one sheath. Internally—*i.e.*, between the heel and the internal malleolus—the tendons of the flexor longus pollicis, the flexor longus digitorum, and the tibialis posticus run beneath the internal annular ligament, the last named being the deepest and in the closest proximity to the ankle-joint, disease of which may originate in the tendon. The relation of the flexor longus pollicis tendon to the posterior ligament is intimate, and is believed to be of advantage in resisting posterior luxation of the astragalus (page 450).

The peroneus longus tendon is thought to be more frequently displaced than any other tendon in the body. When this accident happens, the tendon slips from its groove behind the external malleolus and over the thin posterior border of the latter to its anterior face. This dislocation is favored by (*a*) the length and slenderness of the tendon; (*b*) the shallowness of the groove in which it runs; (*c*) the relative weakness of the single slip of the external annular ligament that covers the tendon; (*d*) the fact that it changes its direction twice between the lower third of the leg and its insertion,—*i.e.*, once at the malleolus and once at the margin of the cuboid.

Disease of the sheaths of the tendons about the ankle-joint is not rare, is apt to be tuberculous, and is favored by the frequent strains and the exposure to cold and wet to which they are subjected, and by their dependent position and remoteness from the heart.

Their relation to disease of the tarsal bones should be remembered (page 437). The approximately vertical direction of the swelling in the early stages is sometimes of use in differentiating teno-synovitis from ankle-joint disease (page 451).

The involvement of the tendon-sheaths in sprain of the ankle-joint (page 450) adds to the duration of the disability produced by that accident.

On the sole of the foot the dense plantar fascia is of importance in relation to infection or suppuration beneath it. Of its three divisions (page 659), the central one is much the strongest. With the intermuscular septa that run from its lateral borders into the sole and separate the flexor brevis digitorum from the abductor minimi digiti externally and from the abductor hallucis internally, it makes a compartment the floor of which is rarely penetrated by inflammatory or purulent effusions. An abscess beginning in the mid-region of the sole beneath the plantar fascia may pass forward between the digital slips or upward through the interosseous spaces, or along the tendon-sheaths to the ankle. More rarely apertures in the plantar fascia permit suppuration to spread through it to the subcutaneous region of the sole. The abscess cavity then consists of two portions connected by a narrow neck, *abcès en bouton de chemise* (Tillaux).

The lateral progress of such an abscess—through the intermuscular septa above described—is easier than penetration of the strong central leaflet of the plantar fascia.

It will be noted that the three compartments into which the sole is then divided are analogous to the thenar, hypothenar, and central divisions of the palm. Contraction of the plantar fascia, which aids in maintaining the curve of the arch of the foot, as a string would that of its bow, increases that arch, is often associated with the different forms of talipes, and is thought to be one of the common causes of a subvariety,—*pes cavus*. Relaxation or elongation of the plantar fascia favors depression of the normal arch, and hence contributes to the development of the condition known as "flat-foot" (*pes planus*) (*vide infra*).

Club-Foot.—The mechanics of the normal foot have already been sufficiently described (pages 436, 447).

Of the deformities, either congenital or acquired, which are grouped under the name club-foot, it is necessary to describe, from the anatomical stand-point, only the chief varieties.

1. *Talipes equino-varus*, when congenital, is believed to result from retention of the fœtal position,—*i.e.*, from defective development. The inward rotation of the flexed and crossed limbs *in utero*, which in the later periods of fœtal life removes the pressure from the fibular side of the legs and the dorsum of the feet and puts the latter in the position of extreme flexion with the soles—instead of the tops—of the feet against the uterine walls (Berg), does not take place. This is the commonest of all the forms of club-foot. When it is acquired, it may be due to paralysis of those muscles that oppose the adduction and extension of the foot,—*i.e.*, chiefly of

the extensor longus digitorum and the peronei. The muscles that draw up the heel, —the gastrocnemius and soleus,—the muscles that elevate the inner border of the foot and adduct it,—the tibialis anticus and posticus and the flexor longus digitorum, —are not resisted; or, if the case is congenital, are assisted by the position of the foot, which is therefore found with (*a*) the heel elevated; (*b*) the inner edge of the sole drawn upward; (*c*) its axis turned inward; (*d*) the sole shortened, partly through contraction of the plantar fascia.

In marked cases the calcaneum will be almost vertical, as will the astragalus, which will also be rotated forward so that its head may have two articular facets, one of them projecting on the dorsum; the scaphoid is atrophied and is close to the inner malleolus; the cuneiform bones accompany it, and the cuboid becomes the chief point of support of the weight of the body.

Corresponding changes occur in the metatarsal bones and phalanges, which may be at right angles to the line of the inner side of the leg.

Pure *talipes varus*, in which the elevation of the heel is absent, is very rare. The other varieties of club-foot are seldom congenital.

2. *Talipes Valgus.*—The foot is abducted and the outer border elevated by the peronei, the inner side being correspondingly depressed and the arch of the foot flattened out.

3. *Talipes Equinus.*—The heel is drawn up by the gastrocnemius and soleus; the patient walks on the balls of the toes; the os calcis and the astragalus are changed in position as in equino-varus. The astragalo-scaphoid and calcaneo-cuboid joints are much flexed, so that the scaphoid may even be in contact with the os calcis.

4. *Talipes Calcaneus.*—The extensor longus digitorum and the extensor proprius pollicis raise the toes and with them the foot, so that the anterior portion of the os calcis is elevated and the astragalus is rotated backward until its articular surface points in that direction. The patient walks on the heel.

Flat-foot results from weakness or relaxation of plantar muscles, fasciæ, and ligaments, especially the inferior calcaneo-scaphoid (page 445). When, in persons who stand much of their time, or in those with defective ankles originally, this ligament yields, the head of the astragalus is carried downward and inward by the body weight, which, owing to the width of the pelvis, the obliquity of the femur, and the curve of the tibia, is transmitted to the astragalus somewhat from without inward. This is associated with abduction of the foot, resisted by the internal lateral and calcaneo-astragaloid ligaments. This sinking of the astragalus and increased prominence of the internal malleolus may be seen in many normal feet when the weight of the body is thrown on one foot (page 449). In well-marked cases of flat-foot the tibialis posticus fails to resist this change effectually, the peronei add to the abduction or shortening, the arch of the sole of the foot entirely disappears or may even become a rounded downward curve, the deltoid ligament stretches, as do the long and short plantar ligaments, and the head of the astragalus, the scaphoid tubercle, and the sustentaculum tali (page 449) become unduly prominent and may be the main points of support.

Two bursæ about the foot are of enough importance to demand attention.

The retrocalcaneal bursa lies between the os calcis and the tendo Achillis, the depressions at the sides of which are effaced when the bursa is distended. The corresponding obliteration of the anterior depressions just beneath the malleoli (page 451), which occurs in ankle-joint disease, does not take place. Flexion or extension of the foot or contraction of the calf muscles is painful.

Bunions.—There may be normally a bursa over the metatarso-phalangeal joint of the great toe, or an "adventitious" bursa—formed by dilatation of lymph-spaces, condensation of connective tissue, and localized effusion—may develop there, as a result of pressure and friction from badly fitting shoes. The great toe is forced outward, the internal lateral ligament of the articulation is elongated, the joint is made unduly prominent, the head of the first metatarsal bone sometimes enlarges, and the cartilage over its inner surface not uncommonly atrophies and disappears, leaving a communication between the bursal sac and the synovial cavity of the joint. Flat-foot and all degrees of valgus tend to produce a similar condition by exposing the

inner border of the foot—and thus the first metatarso-phalangeal joint—to excessive pressure.

Adventitious bursæ are found over the external malleolus,—"tailor's bursa,"—over the cuboid in equino-varus, and at other points exposed to pressure in the different forms of club-foot.

SURFACE LANDMARKS OF THE LOWER EXTREMITY.

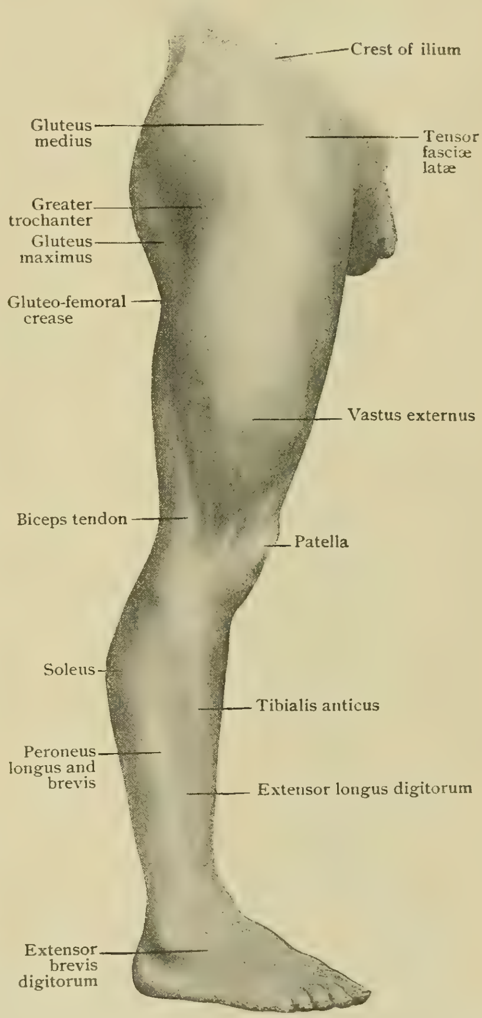
1. **The Buttocks and Hip.**—The iliac furrow (page 349) indicating the line of the crest of the ilium, with the external oblique above and the gluteus medius below, passes forward to the anterior superior spine, and is more or less effaced posteriorly where the crest is covered by the flat tendon of the erector spinæ. The posterior superior spine is always indicated by a surface depression.

In women the continuous layer of fat passing from the loin to the buttock blends the surface forms of these regions into one uniform curve (Thomson), and there is no such marked definition of them as is seen in the male.

The rounded prominence of the buttock (Fig. 632) is due partly to subcutaneous fat, partly to the thick muscular mass of the gluteus maximus, especially developed in man by reason of his assumption of the upright position. It is more prominent posteriorly, becomes flattened as it passes outward, and ends in a distinct depression (Fig. 632) at the tendinous insertion of that muscle just behind and below the greater trochanter. Although the trochanter is on a plane external to that of the iliac crest, the hollow between it and the ilium is so obliterated by the gluteus medius and minimus muscles that it ordinarily does not appear as a surface prominence. Its upper border—on a level with the centre of the acetabulum—is indistinct on account of the presence of the gluteus medius tendon which passes over it to be inserted into the outer surface of the trochanter.

In front the muscular eminences where the region of the buttock passes into that of the hip are due to the gluteus medius above and more anteriorly to the tensor faciæ latæ (Fig. 632), which shows as a broad elevation just behind a vertical line drawn through the anterior superior spine and just below the forepart of the iliac crest. It can be best seen if the thigh is in abduction and inward rotation.

FIG. 632.



Lateral surface of right leg, showing modelling on living subject.

As the skin of the buttock is made tense when the thigh is flexed on the pelvis, the *fold of the nates* (gluteo-femoral crease), due to creasing or drawing in of the skin, is formed when the thigh is extended. It begins just below the level of the

tuberosity of the ischium, runs horizontally outward, and crosses the middle of the lower edge of the gluteus maximus, part of which—the inner—is therefore above it and part—the outer—below it. In flexion of the hip the gluteus maximus is flattened and the skin stretched over it, and hence this fold is more or less completely effaced. As flexion is an almost constant early symptom of hip-joint disease (page 381), and is usually associated with atrophy of the muscles moving the joint, the obliteration of the gluteo-femoral crease, characteristic of this disease, can readily be understood.

In women, on account of the thickness of the supragluteal layer of fat, the gluteo-femoral crease is longer and deeper than in men.

The various bony points of this region have been described (pages 345, 349), as have the different lines and measurements employed in the diagnosis of fractures of the neck of the femur and of dislocation (pages 362, 364, 367).

2. **The Thigh.**—(*a*) *Anterior crural region.* The hip passes insensibly in front and below into the region of the thigh. The inguinal furrow, a valuable landmark, separates the surface of the abdomen from that of the thigh (page 1774). It indicates the line of Poupart's ligament, which may be felt, in the absence of much subcutaneous fat, from the iliac spine to the pubic spine, more easily over its inner half, and still more easily if the thigh is in extension, abduction, and outward rotation.

The ligament is relaxed by flexion, adduction, and inward rotation of the thigh, and with it, to some extent, the deep fasciæ of the thigh and abdomen; therefore that position is the one most favorable to reduction of either inguinal or femoral hernia by taxis (pages 1770, 1774).

Below this a second furrow—"Holden's line"—is sometimes seen with the thigh in slight flexion, beginning at the scroto-femoral angle and becoming less distinct until it is lost at or over the supratrochanteric space. It runs across the front of the capsule of the hip-joint and is lost in the presence of synovitis of that joint. It is often indistinct, and in some subjects cannot be made out at all (Treves).

On the line of this furrow, and just external to a vertical line drawn through the middle of Poupart's ligament, the head of the femur can sometimes be made palpable by extension and rotation of the thigh, but this is rarely possible in fat or muscular persons.

The depression or flattening of Scarpa's triangle (page 639) can usually be seen. The tendon of origin of the adductor longus—made prominent by abduction—and the upper portion of the sartorius, emphasized by flexion and outward rotation of the thigh with the knee bent, mark its inner and outer borders respectively. The sartorius, continued downward, becomes flattened and is lost in the rounded fulness on the inner side of the knee. Just internal to a line bisecting the triangle the femoral artery may be felt and its pulsations sometimes seen. A very trifling depression is occasionally present near the inner angle at the base of the triangle, and then indicates the position of the saphenous opening (page 635), the centre of which is from one to one and a half inches below and the same distance external to the pubic spine, which is on a transverse line drawn through the upper margin of the greater trochanter. From the apex of the triangle the shallow groove, extending towards the inner side of the knee, marks the course of the sartorius and the interval between the quadriceps extensor and the adductors. To the outer side of the triangle the rectus can be seen, showing below the anterior superior spine in the interval between the sartorius and the tensor fasciæ latæ; it runs down the front of the thigh, giving it its convex fulness, and narrowing to its ending in the flattened quadriceps tendon, the edges of which stand out when the leg is strongly extended on the thigh. The obliteration of Scarpa's triangle, in full extension of the thigh, is due to the thrusting forward of the overlying tissues by the neck and the upper end of the shaft of the femur.

To the inner side of Scarpa's triangle, below and posteriorly to the adductor longus, the other adductors and the gracilis give the rounded outline to the inner side of the upper thigh. Near the knee, when the leg is flexed, the tendon of insertion of the adductor magnus can be plainly felt between the sartorius and vastus internus. The latter muscle stands out along the lower half of the thigh and is still more prominent near the knee, where it becomes superficial between the rectus and the sartorius.

On the outer side the vastus externus gives the thigh its broad, slightly convex surface, down the centre of which there is sometimes a slight vertical groove indi-

cating the position of the ilio-tibial band of fascia between the insertions of the tensor fasciæ latæ and gluteus maximus and the external tibial tuberosity. More posteriorly a distinct longitudinal depression corresponds to the external intermuscular septum, between the vastus externus and the short head of the biceps. At the lower third of the thigh this groove indicates the line of nearest approach of the shaft of the femur to the surface. Elsewhere it is usually so covered by muscular masses that it is not to be felt, even indistinctly. The corresponding internal septum—between the vastus internus and the adductors and pectineus—produces no surface marking.

(*b*) *Posterior crural region.* The hamstrings, descending from beneath the lower edge of the gluteus maximus, cannot at first be separately identified. Lower, a very slight depression may mark the interval between the semimembranosus and the semitendinosus, and the biceps tendon becomes a salient rounded cord.

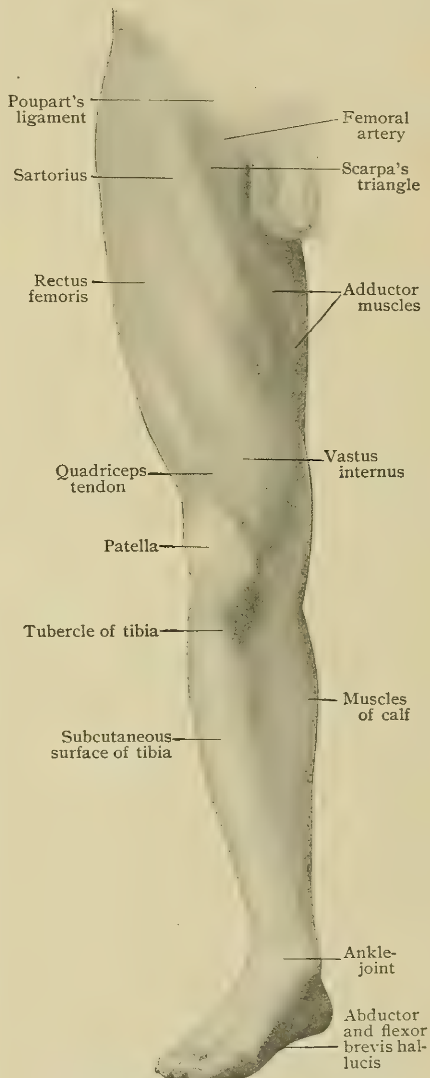
When the limbs are straight with the knees together there should be but a slight interval between the thighs, and that only where the sartorius muscles curve back to lie along the inner surface of the limb. In women, owing to the greater quantity of subcutaneous fat, the thighs may be in contact all the way down (Thomson).

3. **The Knee.**—On the anterior surface the quadriceps tendon and the ligamentum patellæ are made more prominent by strong extension of the leg, and on each side of the ligament the little eminence made by the protrusion of the soft subpatellar fat becomes visible. The angle made by the axes of the tendon and ligament should be noted (page 418).

The outline of the patella is easily felt and can usually be seen. Above it is a slight depression. At its sides are two concavities—the inner of which is a little more marked, as the inner border of the patella is the more prominent—which in fat persons may disappear, as they do, together with the suprapatellar depression, in synovitis of the knee-joint (page 413). Both anteriorly and laterally the landmarks have been sufficiently described (pages 367, 390).

Posteriorly the popliteal space—the ham—is slightly convex during extension of the leg and deeply concave when it is flexed. The boundaries, the relations of the hamstring tendons, of the ilio-tibial band externally and of the sartorius tendon internally have been described (pages 409, 646). At the lower portion of the space the converging fleshy bellies of the gastrocnemius may be felt.

FIG. 633.



Antero-median surface of right leg, showing modelling on living subject.

4. **The Leg.**—The landmarks relating to the tibia (page 390) and fibula (page 396) have been described. Between these bones the belly of the tibialis anticus causes a distinct prominence, to the fibular side of which is the narrower and less-marked elevation due to the extensor longus digitorum. Below the middle third of the leg these muscles are tendinous, but by dorsal flexion of the foot and of the toes (exten-

sion) they can be made to stand out with the tendon of the extensor proprius hallucis between them; to the outer side of the extensor longus digitorum tendon a slight groove indicates the interval between that muscle and the peroneus tertius. The latter—as a muscle peculiar to man and probably developing as a result of his assumption of the erect posture—is not invariably present. Above, between the extensor longus digitorum and the soleus, the peroneus longus makes a longitudinal elevation shading off below—where the fleshy fibres become tendinous—into the flatter peroneus brevis.

Posteriorly the swell of the calf is formed by the gastrocnemius, and its surface markings are due to the peculiar arrangement of the fleshy and tendinous portions of that muscle. When the calf muscles are in action, as in standing on the toes, it will be seen that the inner head is the larger and descends somewhat lower than the outer head; and the lateral borders of the soleus will be seen coming to the surface beyond the lower part of the gastrocnemius and the tendo Achillis and showing as curved eminences, of which the outer is the longer.

5. **The Ankle and Foot.**—The bony landmarks have been described (pages 390, 396, 437, 449, 453).

At the front of the ankle the extensor tendons are easily recognized. The largest and most internal is that of the tibialis anticus; then, in order, the extensor proprius hallucis, extensor longus digitorum, and—when present—the peroneus tertius. Beneath the tendons of the long extensor and just below the external malleolus, the fleshy belly of the short extensor of the toes, filling the space between the os calcis and astragalus, can easily be felt as a soft swelling over the outer part of the tarsal region, and is distinctly visible when in action. On either side of the tendinous elevation, on a level with the line of the ankle-joint and in front of each malleolus, is a little depression. This is effaced when the capsule is distended by effusion (page 451). The two fleshy masses on the inner and outer border of the foot are due respectively to the abductor and flexor brevis hallucis and the abductor and flexor brevis minimi digiti. The dorsal interossei project upward slightly between the metatarsal bones. The lines on the dorsum of the foot corresponding to the various joints have been described (page 453).

Behind the ankle and at the sides of the tendo Achillis—between it and the posterior surfaces of the malleoli—are two concavities, of which the outer is the deeper. In it the tendons of the peroneus longus and brevis may be felt, the latter the nearer to the fibula. In the inner concavity lie, in order from the malleolus backward, the tendons of the tibialis posticus, the flexor longus digitorum, and the flexor longus pollicis.

On the sole of the foot the abductors of the great and little toes show somewhat on the surface, but the chief outlines are determined by the arch of the foot, the strong plantar fascia, and the thick integument. The digital creases have but little practical value.

As the foot, taken as a whole, acts as a lever, and as the calf muscles are attached to the heel,—the short end of such a lever,—it follows that the development of these muscles will stand in some relation to the length or projection of the heel. As a short lever will require the application of a greater force to produce the same result than will a long lever, we find the most marked muscular development of the calf associated with a short foot and a short heel, while a long foot and a long heel are the usual concomitants of a poorly developed calf (Thomson). The athletic feats of some runners with poorly developed calves may sometimes be explained by observing the unusual length and projection of the heel.

THE VASCULAR SYSTEM.

THE vascular system is composed of the organs immediately concerned in the circulation throughout the body of the fluids which convey to the tissues the nutritive substances and oxygen necessary for their metabolism and carry from them to the excretory organs the waste products formed during metabolism.

The system is usually regarded as being composed of two portions, the one consisting of organs in which circulates the red fluid which we term blood, while the organs of the other contain a colorless or white fluid known as lymph or chyle ; the former of these subsystems is the *blood-vascular system* and the latter is the *lymphatic system*. It must be recognized, however, that the two systems communicate, and that the lymphatic system develops as an outgrowth from the blood-vascular system ; so that while it proves convenient for descriptive purposes to regard the two systems as distinct, nevertheless, they are intimately associated both anatomically and embryologically.

THE BLOOD-VASCULAR SYSTEM.

The blood-vascular system consists of (1) a system of canals known as *blood-vessels*, traversing practically all parts of the body, and (2) of a contractile organ, the *heart*, by whose pulsations the blood is forced through the vessels. The vessels are again divisible into (1) vessels which carry the blood from the heart to the tissues and are known as *arteries*, (2) exceedingly fine vessels which form a net-work in the tissues and are termed *capillaries*, and (3) vessels which return the blood from the tissues to the heart and are known as *veins*.

THE STRUCTURE OF BLOOD-VESSELS.

Although passing into one another insensibly and without sharp demarcation, where typically represented the arteries, capillaries, and veins present such characteristic histological pictures that they are readily distinguished from one another.

All blood-vessels, including the heart, possess an endothelial lining which may constitute a distinct inner coat, the *tunica intima*, or, as in the capillaries, even the entire wall of the vessel. Usually, however, the intima consists of the endothelium reinforced by a variable amount of fibro-elastic tissue in which the elastica predominates. Except within the walls of capillaries, external to the intima lies a thick middle coat, the *tunica media*, which typically is composed of intermingled lamellæ of involuntary muscle and elastica and fine fibrillæ of fibrous tissue. Outside the media follows the *tunica externa* or *adventitia*, which, although usually thinner than the middle coat, is of exceptional strength and toughness—characteristics conferred by its fibro-elastic tissue and upon which the integrity of a ligature often depends.

It should be noted that the endothelial tube is the fundamental and primary structure in all cases, the other coats being secondary and variable according to the size and character that the vessel attains. The customary division into the three coats is more or less artificial and in the larger vessels is often uncertain. The recognition of an inner endothelial and an outer musculo-elastic coat often more closely corresponds to the actual arrangement of the tissues than the conventional subdivision into three tunics.

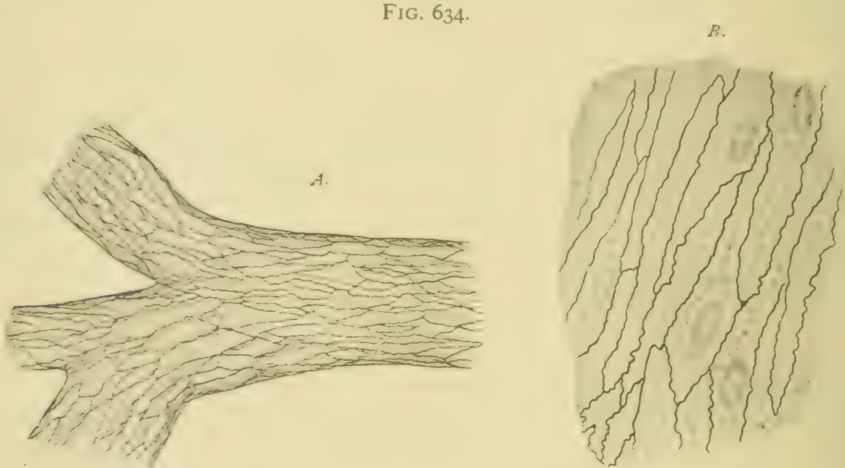
The **endothelial lining** of the arteries consists of elongated spindle-shaped plates united by narrow sinuous lines of cement substance which, after silver-staining, map out the irregular contours of the cells with diagrammatic clearness (Fig. 634). At the junction of the plates, occasional accumulations of the cement substance mark minute intercellular areas, the *stigmata*, that indicate points of less accurate apposition. Within the veins, the endothelial plates are shorter and broader than in the arteries, approaching somewhat irregular polygons in outline. The demarcation of

the endothelium into distinct cells is less evident in the capillaries than in the larger vessels, in some cases a continuous syncytial sheet replacing the definitely outlined plates. The presence of a relatively small oval nucleus is readily demonstrated by suitable stains.

The **involuntary muscle** varies in amount, from the imperfect single layer of muscle-cells found in the arterioles, to the robust muscular coat of many lamellæ in the larger arteries. It is relatively best developed in arteries of medium size, where the muscle occurs in distinct broad or sheet-like bundles between the strands of elastic tissue. The component fibre-cells are short and often branched and, for the most part, circularly disposed. The distribution of the muscular tissue is much less regular and constant in the veins than in the arteries, since in many it is scanty, in some entirely wanting, and in a few veins excessive, occurring in both circular and longitudinal layers. The *striated muscle* found in the large vessels communicating with the heart resembles that of the cardiac wall from which it is derived.

Connective-tissue is represented in the arteries and veins by both fibrous and elastic tissue. The former is present as delicate or coarser bundles of fibrillæ that extend between the other components of the vascular wall.

FIG. 634.



A, endothelium of arteriole after silver-staining; × 200. *B* endothelial cells more highly magnified. × 500.

The **elastic tissue** is very conspicuous in all arteries save the smallest, and in many veins. It presents all variations in amount and arrangement from loose networks of delicate fibres in the smaller vessels to robust plates and membranes in the largest arteries. Within the intima of the latter, the elastica often occurs as sheets broken by pits and perforations, which are, therefore, known as *fenestrated membranes*.

Nutrient blood-vessels are present within the walls of all the larger vessels, down to those of 1 mm. in diameter, and provide nourishment for the tissues composing the tubes. These *vasa vasorum*, as they are called, are usually branches from some neighboring artery, their favorite situation being the external coat within which they ramify, breaking up into capillaries that, in the larger vessels, invade the adjacent media. The blood from the vascular wall is collected by small veins that accompany the nutrient arteries, or, as in the case of the veins, empty directly into the venous trunk in whose walls they course.

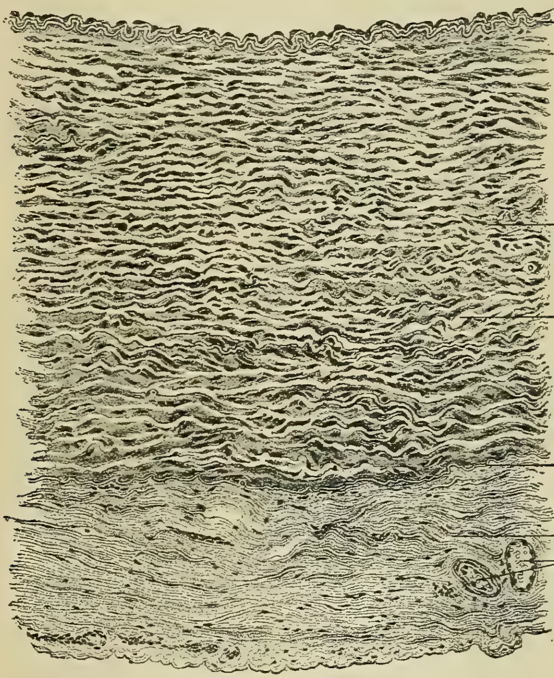
Lymphatics are represented by spaces both within the muscular tissue and beneath the endothelium. In certain situations, conspicuously in the brain and the retina, the blood-vessels are enclosed within lymph-channels, the *perivascular lymph-sheaths*, that occupy the adventitia.

The **nerves** distributed to the walls of blood-vessels, especially to the arteries, are numerous and include both sympathetic and spinal fibres. The former are des-

tined particularly for the muscular tissue and, therefore, are directed to the media, although vessels in which muscle is wanting, as in certain veins and the capillaries, are not without nerves. From the plexus that surrounds the vessel, notably rich about the arteries, nerve-fibrillæ penetrate the media and end among the muscle-fibres in the manner usual in such tissue (page 1015). Special sensory nerve-endings have been described in both the external and internal tunics.

The Arteries.—Since the arrangement of the component tissues is most typical in arteries of medium size (from 4–6 mm. in diameter), the radial artery may appropriately serve for description. Seen in cross-section (Fig. 635), after the usual methods of preservation and staining, the *intima* presents a plicated contour as it follows the foldings of the *internal elastic membrane* that appears as a conspicuous corrugated light band marking the outer boundary of the inner tunic. The lining endothelial cells are so thin that in profile their presence is indicated chiefly by the slightly projecting nuclei. Between the endothelium and the elastic membrane the

FIG. 635.



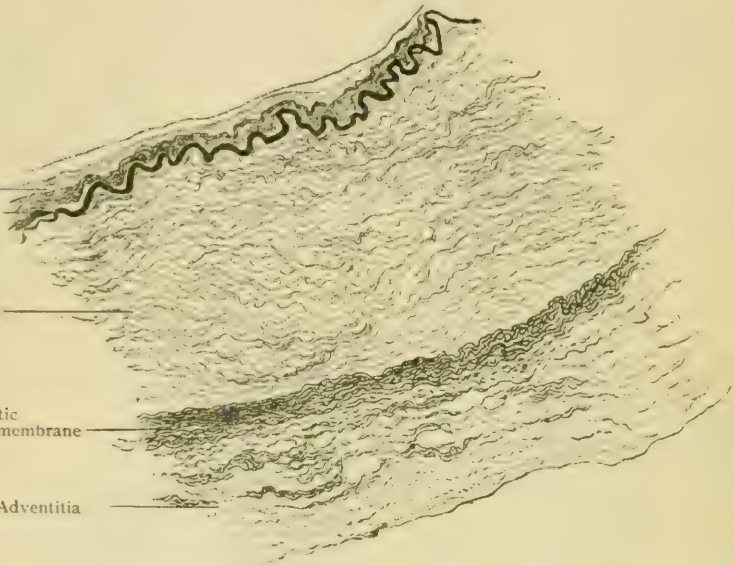
Transverse section of artery of medium size. × 150.

intima includes a thin layer of fibrous and elastic fibrillæ. The *media*, thick and conspicuous, consists of circularly disposed flat bundles of involuntary muscle separated by membranous plates of elastic tissue, that in the section appear light and unstained. After the action of selective dyes, as orcein, the elastica is very conspicuous (Fig. 636). Delicate fibrillæ of fibrous tissue course among the musculo-elastic strands. Beneath the outer coat, the elastica becomes condensed into a more or less distinct *external elastic membrane* that marks the outer boundary of the media. The *adventitia* varies in thickness, in the medium-sized arteries being relatively better developed than in the larger ones. It consists of bundles of fibrous tissue intermingled with elastic fibres of varying thickness. The adventitia contains the vasa vasorum and chief lymph-channels of the vascular wall.

Followed towards the capillaries, the coats of the artery gradually diminish in thickness, the endothelium resting directly upon the internal elastic membrane so long as the latter persists, and afterwards upon the rapidly attenuating media. The elastica becomes progressively reduced until it entirely disappears from the middle

coat, which then becomes a purely muscular tunic and, before the capillary is reached, is reduced to a single layer of muscle-cells. In the precapillary arterioles the muscle no longer forms a continuous layer, but is represented by groups of fibre-cells that

FIG. 636.



Transverse section of artery of medium size, stained to show elastic tissue. × 100.

partially wrap around the vessel, and at last are replaced by isolated elements. After the disappearance of the muscle-cells, the blood-vessel has become a true capillary. The adventitia shares in the general reduction and gradually diminishes in thickness until, in the smallest arteries, it consists of only a few fibro-elastic strands outside the muscle-cells.

In the **large arteries**, on the other hand, the intima and media chiefly undergo augmentation. Although the inner coat greatly thickens and contains a large amount of fibrous tissue and elastica, a conspicuous internal elastic membrane, as seen in the smaller vessels, is lacking, since the elastic plates and membranes are now so abundant that the local accumulation is no longer striking, the boundary between the inner and middle coats being, therefore, less sharply defined. The character of the thickened media also changes, the muscular tissue being relatively reduced and overshadowed by the excessive development of the fibro-elastic tissue, which is arranged in regularly disposed lamellæ separating the muscle-bundles and conferring a more compact and denser character to the wall of the vessel. The adventitia, while relatively thinner than in arteries of medium size, is also increased and consists of robust fibres and plates of elastica, many of which are longitudinally disposed and irregular, although strong, bundles of fibrous tissue. Exceptionally, longitudinal strands of muscle appear in the outer coat next the media. In the roots of the aorta and

FIG. 637.

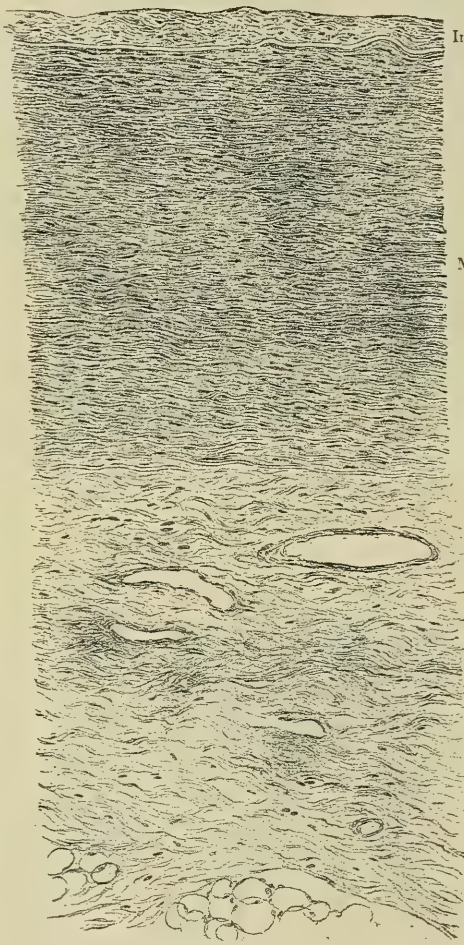
Small arteries in which muscular coat is reduced to single layer of cells. × 150.

pulmonary artery, the media consists chiefly of striated muscle which resembles that of the myocardium with which it is continuous, both vessels having been derived from a common trunk, the bulbus arteriosus, the anterior segment of the primary heart-tube.

The Veins.—The walls of the veins are always thinner than those of corresponding arteries and are more flaccid and less contractile in consequence of the smaller amount of elastic and muscular tissue that they contain.

In veins of medium size (from 4–8 mm. in diameter), the *intima* consists of the lining endothelium, the cells of which are relatively broad and short, a thin layer of fibrous connective tissue and net-works of fine elastic fibres. A distinct internal elastic membrane is seldom present, at most a condensation of elastic fibrillæ marking the outer limit of the inner coat. In some veins, as the cephalic, basilic, femoral, long saphenous, and popliteal, bundles of smooth muscle occur within the intima. In addition to the circularly disposed thin sheets of muscular and fibro-elastic tissue, the *media* contains fibro-elastic plates, sometimes mingled with a few bundles of muscle-cells, that extend longitudinally. In certain veins, as in the saphenous, deep femoral, and popliteal, the longitudinal fibres may constitute a zone beneath the intima to the exclusion of the muscular tissue. The *adventitia* is often thicker than the media, and consists of interlacing fibres and net-works of fibro-elastic strands, the general direction of which is lengthwise. In many veins, particularly in those of the lower extremity, the outer coat contains bundles of longitudinally disposed muscle-cells.

FIG. 638.

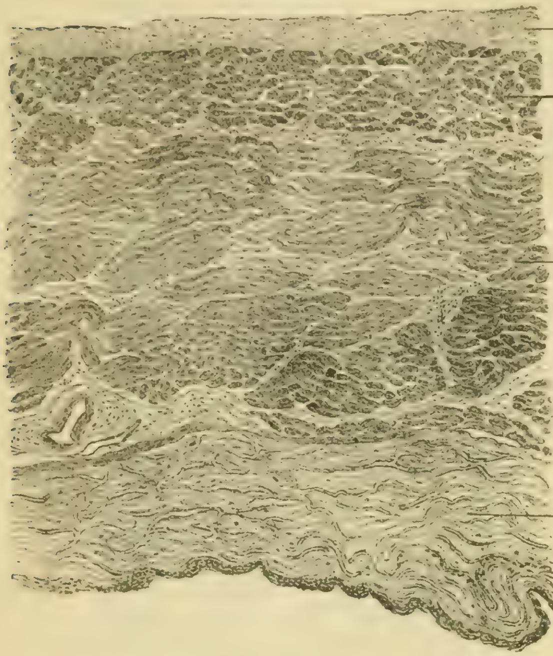


Transverse section of abdominal aorta. × 90.

The **valves** with which many veins are provided consist of paired crescentic folds (Fig. 641) of the intima, covered on both sides with endothelium, containing a small amount of fibro-elastic tissue. The attached border of the leaflets ends in narrow prolongations that extend beyond the free margin of the valve. Between the leaflets of the valve and the wall of the vein lie the pocket-like *sinuses*, which the blood distends when the valve is closed. In the structure of their walls, the **large veins** present many deviations from the typical arrangement. While the intima is only exceptionally increased, as in the hepatic part of the inferior vena cava and the beginning of the portal vein, the media is often markedly thickened. This increase is chiefly due to augmentation of the elastic and fibrous tissue, the muscle remaining comparatively scanty. The splenic and portal veins, however, are particularly rich in muscular tissue; on the other hand, the media may be almost wanting, as in the greater part of the inferior vena cava and the larger hepatic veins.

Lack of muscle within the media is often compensated by an unusual development of such tissue in the adventitia; in some large veins, as in the hepatic portion of the inferior cava, superior mesenteric, or external iliac, the inner half or two-thirds of the outer coat is occupied by robust bundles of longitudinally arranged muscle. In some cases, however, as in the renal and portal veins, the longitudinal muscle invades the entire thickness of the adventitia, or, as in the supra-renal vein, the muscle of the outer tunic may include both circular and longitudinal layers.

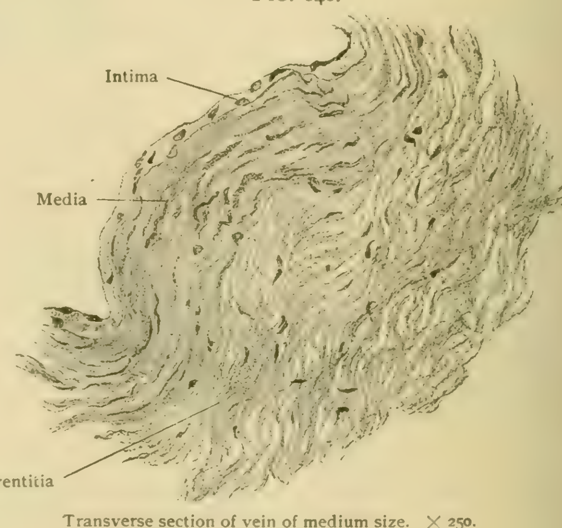
FIG. 639.



Transverse section of pulmonary artery near its root, showing striated muscle. × 150.

The walls of the **small veins** (less than .4 mm. in diameter) consist of only endothelium and connective tissue. The latter represents a relatively robust adventitia and a feebly developed media, muscle-fibres being wanting. Traced towards the capillaries, the connective tissue gradually diminishes until the endothelial coat alone remains. In passing into veins of medium size, at first the muscle-cells are short and scattered and only partly encircle the tube. Farther along the elastica appears in the form of delicate fibres and net-works that increase in size and density as the muscular tissue becomes more pronounced. It is worthy of mention that certain veins, notably those of the brain and pia mater, the dural sinuses, and the blood-spaces of cavernous tissue, are usually entirely devoid of muscle, although in the walls of some of the larger cerebral veins, small strands of such tissue occur.

FIG. 640.

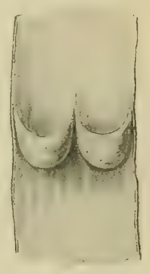


Transverse section of vein of medium size. × 250.

The Capillaries.—The most favorable arrangement for efficient nutrition is manifestly one insuring the passage of the blood-stream at a reduced rate of speed in intimate relations with the tissue-elements. These requirements are met in the capillaries whose collectively increased calibre and thin walls favor slowing of the blood-

stream and the passage of the plasma and oxygen into the surrounding tissues. The walls of the capillaries consist of only the lining plates, the entire vessel being in fact a delicate endothelial tube. The cells composing the latter are elongated lanceolate plates, possessing oval nuclei, united by narrow lines of cement substance. Although the transition from the arterioles is gradual, the final disappearance of the muscle-cells marks the beginning of the true capillaries; the passage of the latter into the veins is less certain, since muscular tissue is wanting in those of small size. In the smallest capillaries two endothelial plates may suffice to encircle the entire lumen; in the larger three or four cells may be required to complete the vessel. Preformed openings (stomata) in the walls of the capillaries do not exist, the passage of the leucocytes and, under certain conditions, also of the red blood-cells (diapedesis) and of small particles of foreign substances, being effected between the endothelial plates. In some capillaries, as in those of the choroid, liver, or renal glomeruli, the usual demarcation of the wall into distinct cells is wanting, the individual endothelial plates being replaced by a continuous nucleated sheet or syncytial layer. Where the capillaries course within fibrous tissue, not uncommonly the vessel is accompanied by delicate strands of connective tissue (*adventitia capillaris*) that suggest an external sheath.

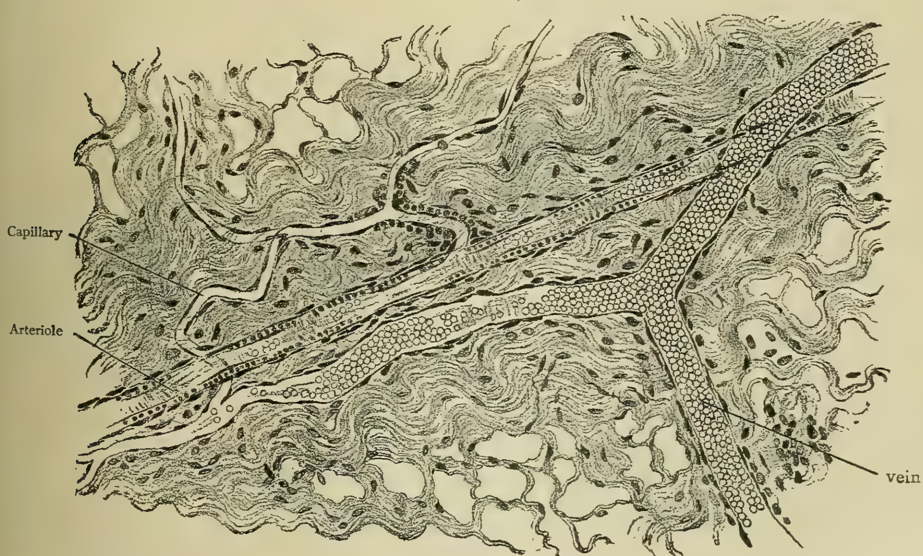
FIG. 641.



Portion of femoral vein, opened to show bicuspid valve.

The capillaries are usually arranged as net-works, of which the channels are of fairly constant size within the tissue to which they are distributed. During life it is probable that none are too small to permit the passage of the red blood-cells, while many admit two or even three such elements abreast. Their usual diameter varies between .008 and .020 mm. The capillary net-works in various parts of the body differ in the form and closeness of their meshes, since these details are influenced by the arrangement of the component elements and by the function of the structures supplied. Thus, in muscles, tendons, and nerves the meshes are elongated and narrow; in glands, the lungs, and adipose tissue they are irregularly polygonal; in the liver-lobules convergingly or radially disposed; while in the subepithelial papillæ of the mucous membranes and the skin the capillaries commonly form loops. In general, it may be assumed that

FIG. 642.



Capillaries arising from arteriole and ending in small vein in omentum. × 200.

the greater the functional activity of an organ, the closer is its capillary net-work. Organs actively engaged in excretion, as the kidneys, or the elimination of substances

from the blood, as the lungs or liver, as well as those producing substances directly entering the circulation (organs of internal secretion), as the thyroid gland, are provided with exceptionally rich and close net-works. The mesh-works within the walls of the pulmonary alveoli are of remarkable closeness and are often narrower than the capillaries surrounding them.

Under the name, **sinusoids**, Minot[1] has grouped the circulation occurring in certain organs, as the liver, in which the capillaries are formed by the invasion and subdivision of the large original blood-channel by the tissue-cords. The resulting sinusoids differ from ordinary capillaries, therefore, in connecting afferent and efferent vessels of the same nature, both being either venous or arterial. Capillaries, on the contrary, form communications between arteries and veins. In consequence of the invagination of the original vessel, its endothelium bears an unusually intimate relation to the tissue-trabeculæ, little or no connective tissue intervening. F. T. Lewis[2] has shown that the Wolffian body and the developing heart also present examples of sinusoidal formation, and suggests the significance of sinusoids as representing a primitive type of circulation.

THE BLOOD.

The fluid circulating within all parts of the blood-vascular system consists of a clear, almost colorless *plasma* or *liquor sanguinis* in which are suspended vast numbers of small free corpuscular elements, the *blood-cells*. The latter are of two chief kinds, the colored cells, or *erythrocytes*, and the colorless or *leucocytes*. The characteristic appearance of the blood is due to the presence of hemoglobin contained within the erythrocytes which, while individually only faintly tinted, collectively impart the familiar hue as well as a certain degree of opacity. That the characteristic pigment is limited to the cells is shown by the lack of color and the transparency of the plasma when examined under the microscope, although to the unaided eye the blood appears uniformly red and somewhat opaque. The most important property of hemoglobin is its great affinity for oxygen which, taken up from the air during respiration and combined as oxyhemoglobin, is carried by the red cells to all parts of the body. When rich in oxygen (containing about twenty volumes) the blood possesses the bright scarlet hue characteristic of arterial blood; after losing approximately one-half of its oxygen and acquiring about an equal volume of carbon dioxide during its intimate relations with the tissues, the blood returned by the veins is dark purplish-blue in color. If the hemoglobin escapes from the erythrocytes into the plasma, the latter becomes deeply tinged and the blood loses its opacity and becomes transparent or "laked." This discharge is known as *hemolysis*.

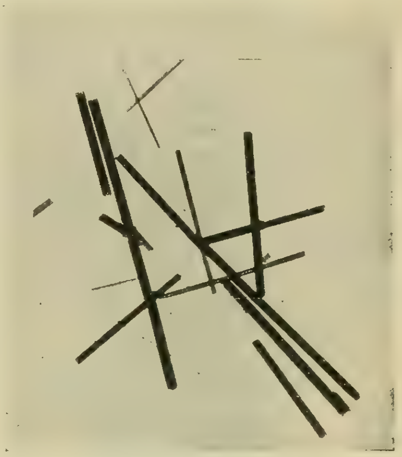
The specific gravity of normal blood is about 1055; its reaction is alkaline and due chiefly to the presence of sodium carbonate. Immediately after withdrawal from the body the blood possesses a characteristic odor that probably depends upon certain volatile fatty acids. When fresh it is slippery to the feel, but after exposure to air becomes sticky. Upon standing it undergoes coagulation, whereby the corpuscles become entangled among the innumerable delicate filaments of **fibrin**, a proteid substance that appears in the plasma after withdrawal of the blood from the body. As the result of this entanglement the corpuscles are collected into a dark-colored, jelly-like mass, the *blood-clot* or *crassamentum*, that separates from the surrounding clear straw-colored *serum*. The latter possesses an alkaline reaction and a specific gravity of 1028. The serum closely resembles the liquor sanguinis, containing about ten per cent. of solid substances, of which about three-fourths are proteids—serum-albumin, serum-globulin, and fibrin-ferment, the latter replacing the fibrinogen present in the plasma before coagulation occurs.

Blood-Crystals.—The chief constituent of the red cells, the hemoglobin, probably exists within the corpuscles as an amorphous mass in combination with other substances (Hoppe-Seyler) from which it must be freed by solution before crystallization can occur. After laking, the coloring matter of the blood, in the form of oxyhemoglobin, separates into microscopic crystals that belong to the rhombic system, usually appearing as elongated rhombic or rectangular plates (Fig. 643).

[1] Proceedings Boston Soc. Nat. History, vol. xxix, 1900.
[2] Anatomischer Anzeiger, Bd. xxv., 1904.

When unusually large or superimposed they exhibit the characteristic crimson hue, but when single and small the hemoglobin crystals are colorless or of a faint greenish-yellow tint. On mixing dried blood with a few grains of sodium chloride and a small quantity of acetic acid and heating until bubbles appear, minute brown crystals are formed in large numbers. These are known as *Teichmann's* or *hemin crystals* and represent one of the products derived from the reduction of hemoglobin. Being yielded by blood from various sources, they are indicative only of the presence of blood and are valueless in differentiating the blood of man from that of other animals. In blood-clots of long standing minute *hematoidin crystals* often appear as yellowish-red plates. This substance is likewise a reduction-product of hemoglobin.

FIG. 643.

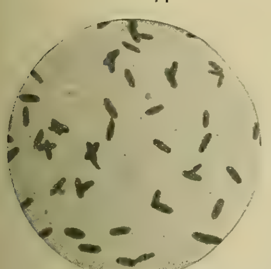


Crystals of oxyhemoglobin from human blood. × 160.

The Colored Blood-Cells.—The mature colored blood-cells, *erythrocytes*, or *red corpuscles*, of man and other mammals (except those of the camel family, which are elliptical in outline) are small, biconcave, circular, nonnucleated discs, with smooth contour and rounded edges. When viewed by transmitted light, the individual "red" cells possess a pale greenish-yellow tint, and only when they are collected in masses or superimposed in several layers is the distinctive blood-color evident. The peculiar form of the corpuscle—biconcave in the centre and biconvex at the periphery—renders accurate focussing of all parts of its broader surface in one plane impossible; hence under the high amplification necessary for their satisfactory examination, the entire cells are never sharply defined and, according to focal adjustment, appear either as light rings enclosing dark centres or *vice versa*. Viewed in profile, the thicker convex marginal areas are connected by the thinner concave centre, the corpuscle presenting a general figure somewhat resembling a dumb-bell.

After fresh blood has been distributed as a thin layer and allowed to remain unshaken for some time, the red cells exhibit a peculiar tendency to become arranged in columns, with their broad surfaces in contact, similar to piles or rouleaus of coin (Fig. 646). Agitation disperses the corpuscles, which, however, may resume their former grouping when again undisturbed. The columns may join one another until a net-work of rouleaus is formed. If the stratum of blood be thin, the red cells usually later separate, but they may retain their columnar grouping.

FIG. 644.



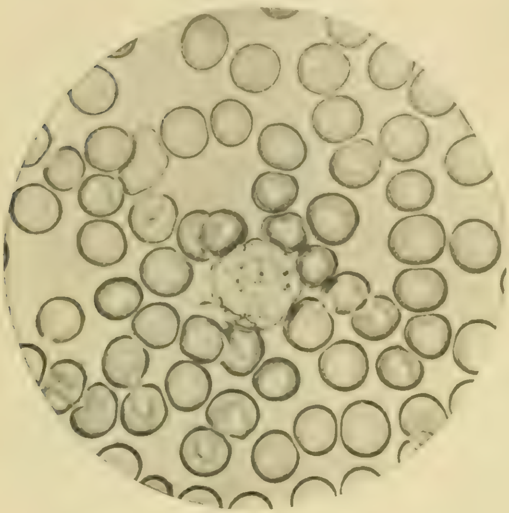
Hemin crystals from human blood. × 250.

The long-accepted biconcave discoidal form of the mammalian erythrocytes has been questioned by Dekhuyzen [1] and, more recently, by Weidenreich [2] and by F. T. Lewis,[3] who believe that the normal form of the red blood-cells is cup-shaped, similar to a sphere more or less deeply indented, thus reviving the conception held by Leeuwenhoek nearly two centuries ago. Although such cupped corpuscles are familiar, they are generally regarded as changed cells resulting from modification of the density of the plasma. The positive testimony of so careful an observer as Lewis as to the occurrence of the cup-shaped red cells within the circulation during life entitle these views to consideration.[4]

[1] Anatomischer Anzeiger, Bd. xv., 1899.
[2] Archiv. f. mikros. Anatom., Bd. lxi., 1902.
[3] Journal of Medical Research, vol. x., 1904.
[4] A critical review concerning the form and structure of the red cells is given by Weidenreich in Ergebnisse d. Anat. u. Entwick., Bd. xiii., 1904.

Dresbach[1] has recorded the presence of elliptical red cells in the blood of an apparently healthy mulatto. The oval corpuscles, which measured .010 mm. by .004 mm., were approximately constant in size, slightly biconcave, and constituted ninety per cent. of all the red cells. They were observed over a period of four months, during which time the number of erythrocytes and leucocytes and the amount of hemoglobin were normal. Dresbach concludes that the oval form was not an artifact, but probably due to developmental variation.

FIG. 645.

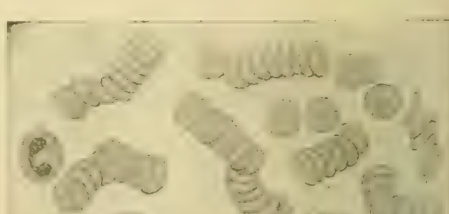


Red cells from human blood; leucocyte seen near centre of field. 505.

The average diameter of the red blood-cells of man is .0078 mm. ($\frac{1}{3200}$ in.), some corpuscles measuring as little as .0045 mm. and others as much as .0095 mm. Their average thickness is about .0018 mm. It is probable that the average diameter is uninfluenced by sex and is constant for all races, although according to Gram, the size of the corpuscles is somewhat greater in the inhabitants of northern countries. The number of red cells normally contained in one cubic millimeter of blood is approximately 5,000,000 in the male and something less (4,500,000) in the female. The number of corpuscles is practically the same whether the blood be taken from the arteries, capillaries, or veins, but is lower in the blood from the vessels of the lower extremity than of the upper, probably owing to the greater proportion of plasma in the more dependent parts of the body. Within the first day after birth, the number of erythrocytes is normally very high; in advanced old age it is usually diminished.

In general, the red blood-cells of mammals are small and their size, which greatly varies in different orders, bears no relation to that of the animal. The corpuscles of man, which are among the largest and exceeded by only those of the elephant (.0094 mm.) and the two-toed sloth (.0091 mm.), are approximated by those of the guinea-pig (.0075 mm.), dog (.0073 mm.), rabbit (.0069 mm.), and cat (.0065 mm.). Those of many familiar mammals are distinctly smaller, as the hog (.006 mm.), horse (.0056 mm.), sheep (.005 mm.) and goat (.004 mm.). The smallest mammalian corpuscles are those of the musk-deer, with a diameter of .0025 mm.

FIG. 646.



Human blood corpuscles; two leucocytes are seen among the red cells, most of which are grouped in rouleaus. × 625.

It is obvious that a positive differentiation of human blood from that of some of the domestic animals, based on the measurement of the red cells, is uncertain and often impossible. The application of the "biological" test has placed a much more reliable and even specific means in the hands of the medico-legal expert. This test depends upon the fact, demonstrated by Bordet, Uhlenmuth, and others, that the blood-serum of an animal that has been repeatedly injected with small quantities of human blood will produce a distinct cloudy precipitate or turbidity when added to a dilute solution of human blood, but will yield no result when added to similar solutions of blood from other animals. An important advantage of this test is that even when the blood is putrid, contaminated, or derived from old dried clots, the characteristic changes occur. Certain exceptional disturbing conditions, such as the presence of

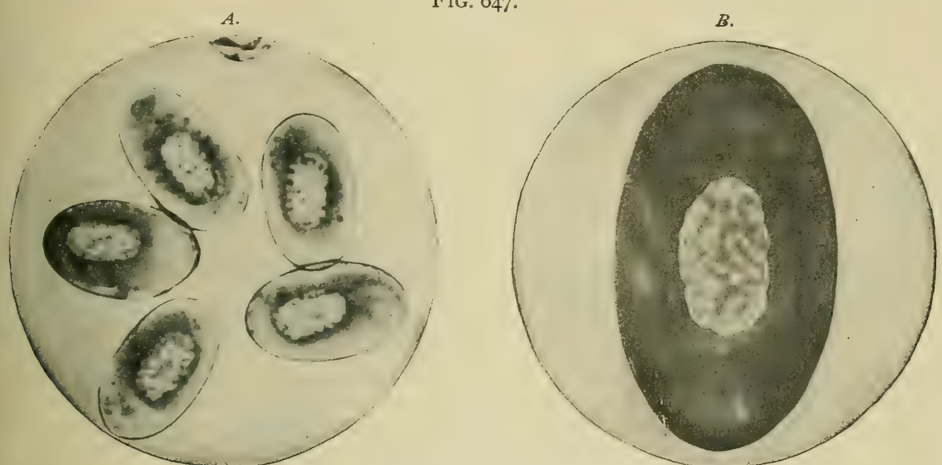
[1] Science, March 18, 1904, and March 24, 1905.

monkey's blood, human lachrymal or nasal secretion, being eliminated, a positive reaction with the serum-test is strong evidence of the presence of human blood.

The nonnucleated condition of the mature erythrocytes is the distinguishing characteristic of mammalian blood as contrasted with the colored corpuscles of other vertebrates, since even in the exceptional oval red cell of the camel family the nucleus is wanting. The mammalian red corpuscles, however, must be regarded as a secondary deviation from the fundamental type represented by the oval nucleated erythrocyte of the other vertebrates, the nucleated embryonic red cell losing its nucleus as maturity is acquired. In general, the oval nucleated red cells are larger than the mammalian nonnucleated discs. The largest erythrocytes are found in the tailed amphibians; those of the amphiuma, the largest known, attain the gigantic length of .080 mm., and are approximately ten times as large as the human red blood-cell.

The **structure** of the red blood-cell has long been and still is a subject of discussion, two opposed views finding ardent supporters. According to the one, held by Schaefer,[1] Weidenreich, and others, the erythrocyte consists of a membranous external envelope inclosing the colored fluid contents. On the other hand, Rollett and many others regard the corpuscle as composed of an insoluble flexible spongy stroma of great delicacy, occupied by the coloring matter or hemoglobin. Although no definite envelope is present, in the sense of a distinct cell-membrane, it is highly probable that a peripheral condensation of the stroma exists. The fact that the

FIG. 647.



Nucleated amphibian red blood-cells; *A*, from newt; *B*, from amphiuma. × 750.

fragments into which the red blood-cells may be broken up after certain treatment, as by heating, retain the appearance and structure identical with the larger original cell, is strong evidence that the hemoglobin has not escaped and, therefore, does not exist in a fluid condition within the cell, notwithstanding the ingenious but scarcely convincing explanations of the phenomena advanced by the supporters of the vesicular structure of these cells. Further, the evidence afforded by those parts of the corpuscles that remain after abstraction of the hemoglobin by water, ether, and other reagents, points to the existence of a distinct stroma, the thicker edges of which appear in profile as outlines of the "ghosts" that then represent the former colored cells.

The erythrocytes are extremely sensitive to a wide range of reagents and conditions and, therefore, require great care in their collection and examination if distortions are to be avoided. Exposure to even a current of air often suffices to produce conspicuous changes in the red blood-cells. Alterations in form may be grouped into those resulting from the action of solutions of lower and of higher density than that of the normal plasma. The latter is conveniently substituted by an .85 per cent. solution of sodium chloride. If the proportion of salt be gradually reduced, the corpuscles show evidences of swelling, at first by losing their concavity on one side and later, as the density of the reagent approached that of water, assuming the spherical form and parting with the hemoglobin and becoming colorless. On the other hand,

[1] Anatomischer Anzeiger, Bd. xxvi., 1905.

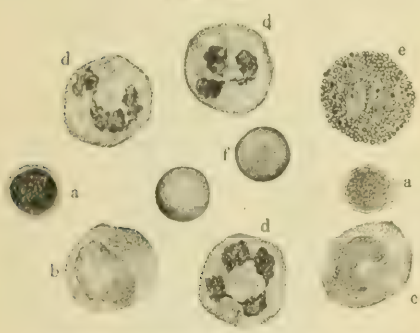
when subjected to saline solutions stronger than the "normal," the exterior of the corpuscles becomes irregular and beset with knob-like projections or spines. When the concentration of the medium is increased, the "crenation" gives place to marked shrinkage and distortion, until the cells lose all resemblance to their normal form.

Upon treatment with water, aqueous dilutions of acetic acid, ether, and other reagents, the erythrocytes are promptly decolorized by the extraction of the hemoglobin. An interesting modification of the phenomenon may be produced by solutions of tannic acid or potassium bichromate of varying strength. When the reaction is vigorous, the decomposed hemoglobin is caught within the cell and appears as a mass somewhat resembling a nucleus. When the reaction is feeble, as with very weak solutions, the hemoglobin is less suddenly precipitated, and appears as a minute projection attached to one part of the exterior of the decolorized corpuscle.

Alkaline solutions effect the complete destruction of the red cells. Among the reagents employed in histological investigations, osmic acid (1 per cent.) deserves especial confidence as preserving the form of the red corpuscles. Fixation by heat, so commonly used in the preparation of blood specimens for clinical examinations, produces alterations and often marked changes in the red cells, and, therefore, is unsuitable for histological study of these elements. Attenuation of the central parts of the cells produces appearances that have been mistaken for a nucleated condition of the erythrocytes. Upon cautious application of heat, with precautions against evaporation and drying, the corpuscles extrude portions of their substance which, after separation, resemble miniature red cells.

The Colorless Blood-cells.—It may at once be emphasized that the colorless cells observed within the blood are only incidentally related to the red cells and, further, that they, in part at least, primarily circulate within the lymph-vascular system, from which they are poured into the blood.

FIG. 648.



Varieties of colorless blood-cells seen in normal human blood; *a*, small lymphocytes; *b*, large lymphocyte or mononuclear leucocyte; *c*, transitional leucocyte; *d*, polymorphonuclear leucocytes; *e*, eosinophile; *f*, red cells. × 900.

When examined in fresh and unstained preparations, the colorless cells or **leucocytes** appear as pale nucleated elements which, by their pearly tint and refracting properties, are readily distinguished from the much more numerous surrounding erythrocytes. Their shape is very variable, but when first withdrawn from the body is usually irregularly spherical or oval. When placed on a warmed slide and maintained at the temperature of the body, many of these cells soon exhibit *amœboid motion*, whereby are produced not only alterations in their form, but often also changes in their actual position.

A nucleus is always present, but may be obscured in the contracted spherical condition of the cell by the overlying granular cytoplasm. In the expanded condition, as when the cell is undergoing amœboid change, the nucleus is very evident and the cytoplasm often differentiated into a homogeneous peripheral zone (*exoplasm*) and a central granular area (*endoplasm*) surrounding the nucleus. A distinct cell-wall is absent, although it is probable that a slight peripheral condensation serves to outline the corpuscle. That such condensation does not constitute a definite envelope is shown by the readiness with which foreign particles may be taken into the body of the cell.

Although the size of the colorless corpuscles varies with the type of the cell, as presently described, in general the diameter of these elements is larger than that of the erythrocytes, and is commonly from .010–.012 mm. Their number is much less than that of the red corpuscles, the usual ratio between the white and red cells being about 1:600. Even within physiological limits this ratio varies considerably, from 5000 to 10,000, with an average of 7500, white cells being normally found in one cubic millimeter of blood.

Critical examination of the colorless cells, after fixation and staining, has shown that among the elements collectively designated as the "white cells" or "leucocytes," five varieties are usually present in normal blood. Since the recognition of these forms is sometimes of practical

importance, a brief resumé of their characteristics, based on the descriptions of Ehrlich and of Da Costa,[1] may appropriately here find place.

It should be noted that the differentiation of these cells is founded upon not only their morphological characters, but also the behavior of the granules embedded within their cytoplasm when subjected to certain combination stains. A generation ago Ehrlich divided the aniline dyes into three groups—*acid*, *basic*, and *neutral*. The first includes such dyes as acid fuchsin, orange G or eosin, in which the coloring principle acts or exists as an acid and exhibits an especial affinity for the cytoplasm. The second group, the basic stains, includes dyes, as hematoxylin, methylene-blue, methyl-violet, methyl-green or thionin, in which the coloring principle exists chemically as a base in combination with a colorless acid and particularly affects the chromatin; hence, such are nuclear stains. Neutral dyes, produced by mixture of solutions of an acid and a basic stain, have a selective affinity for certain so-called neutrophilic granules.

Assuming that the blood-film has been fixed by heat and tinged with Ehrlich's "triacid stain" (a combination of solutions of acid fuchsin, orange G, and methyl-green) the following varieties of colorless cells are distinguishable in normal blood:

1. **Small Lymphocytes.**—These are non-granular cells, with an average diameter of .0075 mm. or about that of the erythrocytes, distinguished by a large deeply staining nucleus that occupies almost the entire cell. The meagre cytoplasm is reduced to a narrow peripheral zone, so inconspicuous that it may be overlooked. The small lymphocytes, which constitute from 20–30 per cent. of all the white corpuscles, are the most common derivative from the lymphoid tissues.

2. **Large Lymphocytes, or Mononuclear Leucocytes.**—These elements, about .012 mm. in diameter, possess a relatively small round or oval nucleus, which is usually eccentrically placed and so poor in chromatin that it stains faintly. The cytoplasm is non-granular and comparatively large in amount.

3. **Transitional Leucocytes.**—Assuming that the lymphocytes and leucocytes are related and not distinct elements, the transitional forms represent the developmental stage linking the large lymphocytes with the mature leucocytes. Their distinguishing feature is the indented or kidney-shaped nucleus which usually occupies an eccentric position within the non-granular cytoplasm. The latter, as well as the diameter of the transitional forms, corresponds with that of the large mononuclear leucocyte.

4. **Polymorphonuclear Leucocytes.**—These represent by far the most common type of white cells, of which they constitute about 70 per cent. Their diameter is approximately .010 mm., hence they are somewhat smaller than the transitional forms, but larger than the red cells. Their cytoplasm is relatively large in amount and contains fine neutrophilic granules. On account of the great diversity of the forms that they assume, the nuclei are very conspicuous features of this type of leucocyte. At first sight the nuclei appear multiple; closer examination, however, shows the seemingly distinct nuclei to be connected by delicate processes, so that, although exceptionally two or more isolated nuclei exist and the cells are truly polynuclear, their actual condition is appropriately designated as polymorphonuclear.

5. **Eosinophiles.**—Leucocytes of this type are conspicuously distinguished by the coarse, highly refractive granules within the cytoplasm that display an especial affinity for acid dyes, particularly for eosin. These resemble the polymorphonuclear leucocytes in size (.010 mm.) and in the character of their nuclei, the latter, however, in general being less distorted and commonly eccentrically placed. The eosinophiles are prone to rupture, after which the pale nucleus lies in the midst of a swarm of brightly tinged granules.

Although other types of colorless cells, as myelocytes and mast cells, are of clinical interest, they do not occur in normal blood and, hence, need not be here discussed. An occasional additional type of leucocyte, the *basophile cells*, is rarely present in normal blood. These elements resemble the polymorphonuclear leucocytes, but are distinguished from the latter by the presence within the cytoplasm of closely packed fine granules that possess a strong affinity for basic dyes.

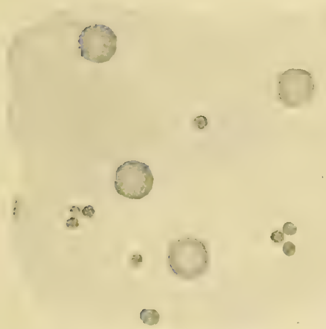
In the foregoing grouping the varieties of white cells are regarded as different stages of elements genetically related and derived from the same sources—a view supported by the early development of the leucocytes. It should be mentioned, however, that Ehrlich and many other hematologists consider the lymphocytes and the leucocytes as entirely distinct elements, believing the former to be derived from lymphoid tissues and the leucocytes exclusively from bone-marrow. Accordingly, the large lymphocytes and the large mononuclear leucocytes are of different nature, although, as universally admitted, their assumed differentiation is at best uncertain. The presence of all forms of white cells in the circulation of the embryo long before the appearance of bone-marrow (Ebner) seems conclusive evidence that the origin of the leucocytes is not limited to the marrow tissue.

The Blood Plaques.—In addition to the erythrocytes and leucocytes, the blood of man and other mammals regularly contains small bodies, the blood plaques

[1] Clinical Hematology. Phila., 1901.

or *thrombocytes*. As they are extraordinarily sensitive to exposure, even to entire disappearance, special precautions are necessary to insure their presence in an unaltered condition in preparations examined. If blood be drawn directly into and mixed with a drop of .85 per cent. salt solution, or, still better, into one of weak osmic acid solution, the blood plaques appear as round or oval discs, from .002–.004 mm. in diameter, usually somewhat less than one-third of the size of the red cells. From these they further differ in being colorless and devoid of hemoglobin and in staining readily in very dilute solutions of methyl-violet. The blood plaques appear faintly granular and contain masses of chromatic substance representing a nucleus. They seem to be minute cells and are capable of undergoing amœboid movement. They possess the ability of rapidly throwing out processes and adhering together on coming into contact with foreign bodies. Their assumed rôle, that of arresting hemorrhage by assisting in the formation of a coagulum, suggested the name, thrombocytes, given them by Dekhuygen. Notwithstanding the attention bestowed upon them, the source of the plaques is still undetermined. This has been variously attributed to disintegration of the leucocytes, to extrusion from the red cells, or from the megakaryocytes, or to destruction of the endothelial lining of the vessels. None of these assumptions can be regarded as established, or even probable, in view of their constant presence and large normal quota—an average of 300,000 plaques in one cubic millimeter of blood.

Fig. 649.



Human blood, showing red cells and blood plaques. × 625.

Granules.—In addition to the corpuscles and the plaques, extremely minute granules occur in varying numbers in normal human blood. The nature of these particles differs. Some are undoubtedly finely divided fat; others, described by H. F. Müller under the name, *hemoconia*, are of uncertain composition, but not fatty; while a certain proportion is probably derived from the disintegration of endothelial and blood-cells. The destruction of the latter is accountable for the minute particles of pigment that are constant, if not numerous, constituents of the circulation.

DEVELOPMENT OF THE BLOOD-VESSELS AND CORPUSCLES.

The earliest blood-vessels appear within the extra-embryonic mesoblast covering the vitelline sac and, therefore, beyond the limits of the embryo proper and entirely independent of the heart and axial trunks. In the lower mammals, the formation of the primary vessels takes place towards the periphery of a limited field, known as the *vascular area*, that encircles only a portion of the vitelline sac; in man the limited proportions of the latter enable the net-work of developing blood-channels to extend completely over the vesicle, so that the vascular area becomes coextensive with the yolk sac. Although the initial stages in the formation of the primary blood-vessels have never been observed in man, since the vessels were already present over the vitelline sac in the youngest embryo so far examined, it is probable that the development of the human vascular tissues is essentially the same as that seen in other mammals.

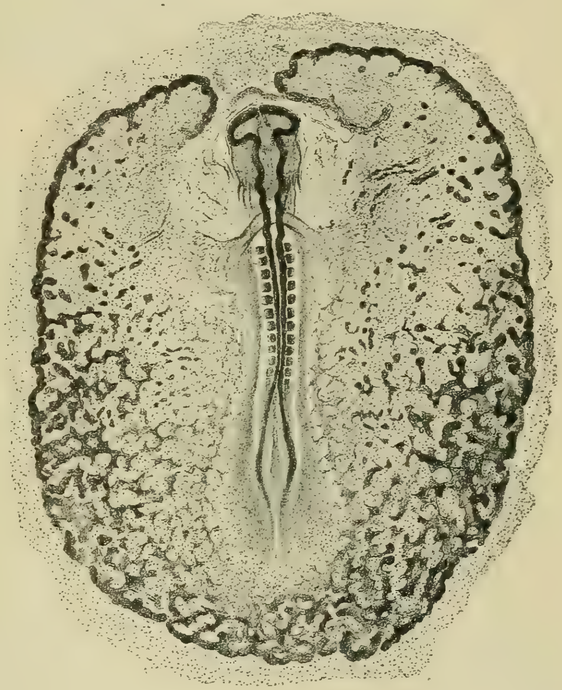
In the rabbit, the first indications of the developing blood-vessels are cords or groups of spherical cells that appear within the deeper, later splanchnic, layer of the mesoblast covering the vitelline sac. These tracts become larger in consequence not only of proliferation, but also of separation of the component cells. The mesoblastic elements surrounding the tracts soon become disposed as enclosing walls, within which the separated cells, now suspended in a clear fluid that has meanwhile appeared, represent the earliest blood-cells.

The channels thus established unite into a net-work of primary blood-vessels that at first occupies the periphery of the vascular area, but later extends towards the

embryo and, after the appearance of the large converging trunks, the vitelline veins and arteries, joins the intra-embryonic trunks that coincidently have been formed.

Although the generally accepted current views relating to the independent origin of the primary blood-vessels within the vascular area have not escaped challenge, it may be regarded as established that the development of subsequent blood-vessels proceeds from the cells constituting the walls of pre-existing channels. The walls of the growing capillaries consist of delicate endothelial plates from which pointed sprouts grow into the surrounding tissue (Fig. 651). These outgrowths, direct prolongations of the cytoplasm of the endothelial cells, are at first solid, but later become hollowed out by the gradual extension of the lumen of the capillary. Vascular loops are often formed by the meeting and fusion of the outgrowths proceeding in opposite directions, the communication being established by the final disappearance of the septum in consequence of the extension of the lumen of the parent vessels. At first represented by only a single layer of endothelial cells, the walls of the larger blood-vessels become reinforced by the additional layers derived from the surrounding mesoblast.

FIG. 650.



Surface view of vascular area of chick embryo with twelve somites (29 hours); net-work of developing blood-vessels, most distinct in periphery of area, is connected with vitelline veins from embryo by faint channels; cephalic segment of neural tube shows brain-vesicles and eye-buds; caudal segment still widely open. × 16.

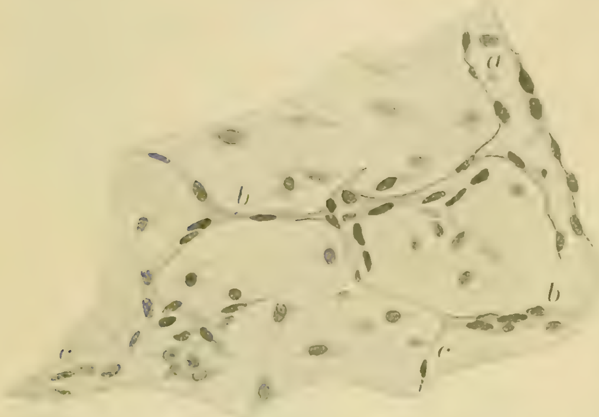
Development of the Erythrocytes.—The first, and for a time the only, blood-cells present within the embryo are the primary nucleated erythrocytes derived probably directly from the mesoblastic elements within the angioblastic areas in which the earliest vessels appear. These cells, the *primary erythroblasts*, separated by the colorless plasma which appears between them, undergo mitotic division, producing nucleated elements that, in turn, give rise to the *primary erythrocytes*. These are spherical, nucleated, and larger (about .012 mm. in diameter) than the adult red cells. At first their cytoplasm is colorless and slightly granular, but soon becomes homogeneous and tinged with hemoglobin.

After the earlier fœtal months, during which proliferation of the blood-cells occurs in all parts of the circulation, the corpuscles engaged in division withdraw to localities in which the blood-current is sluggish and, therefore, favorable for mitosis. Such localities are particularly the liver, spleen, and bone-marrow, the large capillaries and tissues of which afford temporary resting places during proliferation. From the primary blood-cells arise *megaloblasts* and *normoblasts*, from which latter the definite erythrocytes are derived. These changes begin during the second fœtal month, more and more nonnucleated discoidal red cells appearing as gestation advances, so that at birth almost all the nucleated erythrocytes have disappeared from the circulation.

Since the red cells possess only a limited vitality, their constantly occurring death requires the production of new corpuscles. Preceding the development of the spleen and bone-marrow, the liver is the principal centre of blood-formation. Later the splenic and marrow tissues share this function, while *after birth* the red bone-marrow is the chief seat in which the continual additions of new erythrocytes necessary

to maintain the normal quota are made. The production of the new red cells within the marrow proceeds from slightly colored elements, the *erythroblasts*, that by division give rise to normoblasts and nucleated erythrocytes, which latter, upon the distribution of hemoglobin and the disappearance of their nuclei, are transformed into the usual red cells, and as such enter the circulation.

FIG. 651.

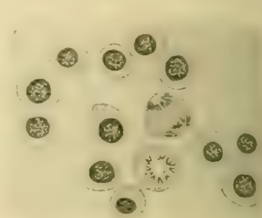


Developing blood-vessels in embryonal subcutaneous tissue; *a*, larger capillary; *b*, young capillaries; *c*, solid protoplasmic outgrowths forming new vessels. × 300.

The disappearance of the nucleus of the normoblasts has long been a subject of discussion and speculation. According to the older view—still, however, accepted by many—the nucleus is extruded from the erythrocyte and undergoes disintegration, thus, in the opinion of some, supplying the source of the blood plaques. According to the more recent views, held by Neumann, Kölliker, Pappenheim, Israel, Ebner, and others, the disappearance of the nucleus is due to its solution and absorption within the erythrocyte. Under normal conditions the immature nucleated red cells do not occur in the circulation. After severe hemorrhage or in other conditions requiring unusual activity of the blood-forming processes, they may be present in large numbers until the normal quota of erythrocytes has been once more established. In view of the constant presence of normoblasts and nucleated erythrocytes within the splenic pulp, the spleen has been regarded as a possible, although under usual conditions limited, source of the red blood-cells. When, however, the necessity for rapidly augmenting the number of red cells arises, the spleen may assume the rôle of an active blood-producing tissue. Since such cells are found also in the thymus, this body probably may be included among the blood-forming organs of early life. There is no satisfactory evidence that the erythrocytes are derived from the colorless cells or from the blood plaques.

Development of the Colorless Cells.—Immediately succeeding the appearance of the primary red cells, the latter are the chief elements within the circulation. In the early weeks, however, colorless cells appear and henceforth are the companions of the erythrocytes. As already noted, the white cells are elements that primarily belong to the lymphatic system, from which they are poured into the blood channels. Genetically, the red and white cells are unrelated.

FIG. 652.



Nucleated embryonal erythrocytes; two dividing cells exhibit mitotic figures. × 600.

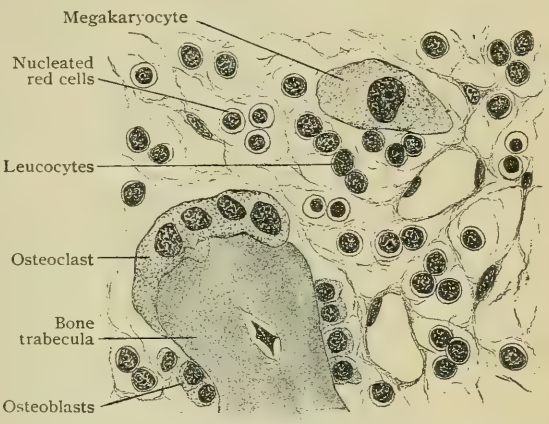
Concerning the origin of the first colorless cells uncertainty exists, although it is generally assumed that they arise from mesoblastic cells and, therefore, to that extent, share with the erythrocytes a common source. According to Maximow,[1] the progenitors of the white cells are *lymphoblasts*, derived from the primitive blood-cells, the *hemoblasts;* the latter are, therefore, the source of both the red and white cells, including the various forms of the colorless corpuscles. The conclusion of Beard,[2] that the first lymphocytes to appear within the embryo owe their production to the metamorphosis of the entoblastic epithelium of the primary thymus, and that the subsequent migration of the lymphocytes so derived establishes foci from which are developed the various masses of lymphoid tissue occurring throughout the

[1] Archiv f. mikros. Anatom., Bd. lxxiii., 1909.
[2] Anatom. Anzeiger, Bd. xviii., 1900.

body, has been challenged by Hammar and by Maximow,[1] who found lymphocytes in the blood and connective tissues before they appear within the thymus. It is probable that the early lymphocytes also originate from mesenchymal cells outside the vessels, which they later enter, aided by their migratory powers. Their subsequent multiplication is effected by division, for the most part mitotic, of the pre-existing cells. This proliferation occurs chiefly within the lymphoid tissue throughout the body, the lymph-nodules, spleen and bone-marrow being the most important localities. The germ-centres of the lymph-nodules (page 936) are seats of especial activity for the formation of the types of colorless cell known as the mononuclear lymphocyte, although whether the proliferating cells originate within the germ-centres, or only complete their division in these situations after being carried from other points (Stöhr), is still unsettled.

From the developmental standpoint, the sharp separation of the colorless blood-cells into lymphocytes and leucocytes, as insisted upon by Ehrlich and his supporters, based on the assumption that the leucocytes originate exclusively within bone-marrow, is not well founded in view of the presence of all the typical forms of white cells, including the polymorphonuclear leucocytes, shortly after the first appearance of the white corpuscles and long before the advent of the earliest bone-marrow (Ebner). For the present, at least, it seems most reasonable to regard the various forms of the white cells as constituting a genetic sequence in which the lymphocyte, leucocyte, and eosinophile represent different stages in the development of elements having a common origin.

FIG. 653.



Section of embryonal bone-marrow, showing nucleated erythrocytes, leucocytes and megakaryocyte. × 625.

In addition to the red blood-cells in various stages of development and the different types of leucocytes, peculiar huge elements early appear in the embryonic blood-forming organs, and after birth in bone-marrow. These giant cells, or *megakaryocytes* (Howell), are distinguished by their large, irregularly lobulated but single nucleus from the osteoclasts, since the nuclei of the latter are usually oval and multiple. The megakaryocytes are often observed containing within their substance the remains of both white and red cells; they are, therefore, regarded as phagocytes upon which devolves the removal of effete blood-corpuscles. Their origin is uncertain, by some (Howell, van der Stricht, Heidenhain) being referred to the leucocytes, and by others (Kölliker, Kuborn) to the endothelium of the vessels, while Ebner regards those within the bone-marrow as probably derived from fixed connective-tissue cells of the reticulum. Neither form of these giant marrow-cells is normally found within the post-natal circulation.

THE HEART.

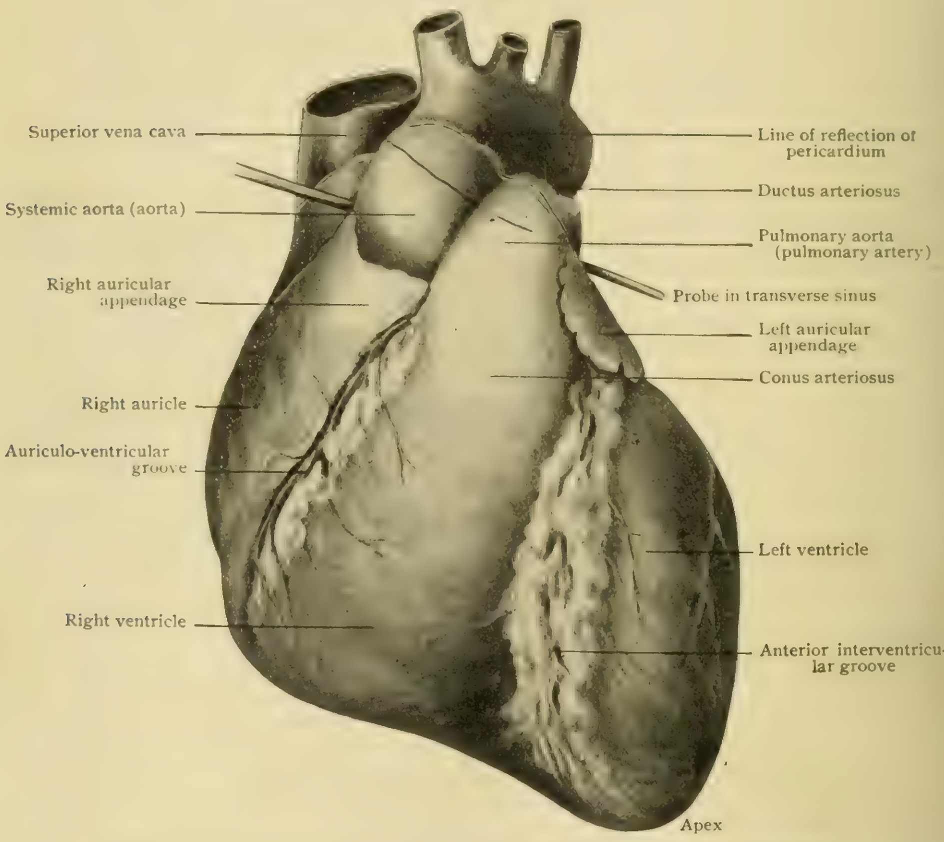
General Description.—The heart is a hollow, muscular organ of a somewhat conical shape, situated in the lower part of the thoracic cavity, behind the lower two-thirds of the sternum. It is enclosed within a double-walled serous sac, the *pericardium*, and has a somewhat oblique position in the thorax, its *base* (**basis cordis**) looking upward, dorsally, and to the right, while its *apex* (**apex cordis**) points downward, ventrally, and to the left. In consequence of this obliquity about two-thirds of the organ lies to the left and one-third to the right of the median plane of the body.

[1] Archiv f. mikros. Anatom., Bd. lxxxiv., 1909.

It may be regarded as possessing two surfaces, which are not, however, distinctly separated, but pass into each other with rounded edges, especially upon the left side. One of these surfaces looks forward and somewhat upward, and is separated by the pericardium and some loose areolar tissue from contact with the sternum and the lower costal cartilages, the thin anterior edges of the lungs and pleuræ also intervening to a considerable extent; this is the *antero-superior surface* (**facies sternocostalis**), and for convenience it may be more briefly termed the *anterior surface.* The other, the *postero-inferior* or *posterior surface* (**facies diaphragmatica**), rests directly upon the upper surface of the diaphragm.

At about one-third of the distance from the base to the apex a deep circular groove, more distinct upon the posterior surface, surrounds the heart, separating an

FIG. 654.



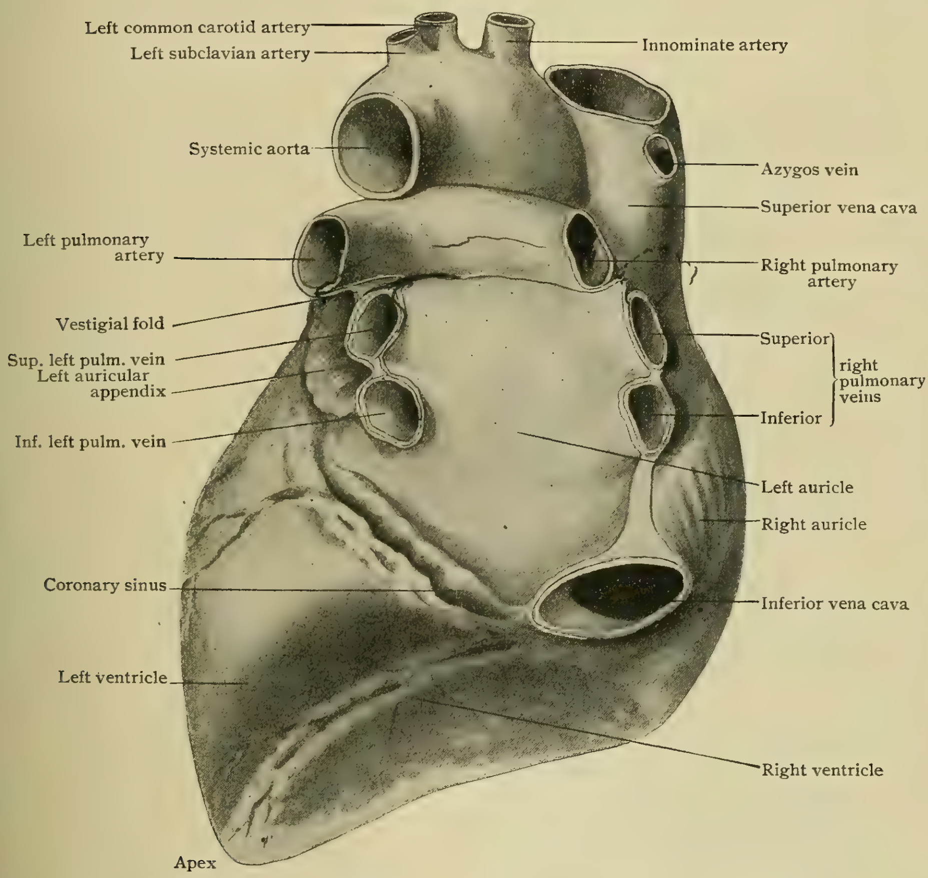
Anterior aspect of heart hardened in situ; probe lies in transverse sinus of pericardium.

upper thin-walled auricular portion of the organ from a lower thick-walled ventricular one; this groove is termed the *auriculo-ventricular groove* (**sulcus coronarius**), and contains the proximal portions of the coronary vessels which supply the heart's substance. Extending towards the apex from this groove, two other shallower grooves are to be observed, one situated towards the right side of the anterior surface and the other upon the posterior surface. These grooves, which also lodge portions of the coronary vessels, are the *anterior* and *posterior interventricular grooves* (**sulci longitudinales**), and mark the line of separation of the ventricular portion of the heart into two chambers known as the *right* and *left ventricles.* From the base of the right ventricle a large blood-vessel, the *pulmonary aorta* or *pulmonary artery*, arises, while from the base of the left ventricle, and almost immediately posterior to the root of the pulmonary aorta, the *systemic aorta* takes its origin. The orifices by which each of these

great vessels communicates with its ventricle are guarded by special valves known as the *semilunar valves.*

The auricular portion of the heart rests upon the posterior part of the base of the ventricular portion, and is best viewed from the posterior surface (Fig. 655), since it is almost completely hidden anteriorly by the two aortæ. Like the ventricular portion, it is composed of two separate chambers, which are not, however, very apparent on surface view. These chambers are the *right* and *left auricles*, and communicate with the corresponding ventricles by *auriculo-ventricular orifices* guarded by special *auriculo-ventricular valves.* From the lateral part of the anterior surface of each auricle a process, the *auricular appendix*, arises. These appendices are

FIG. 655.

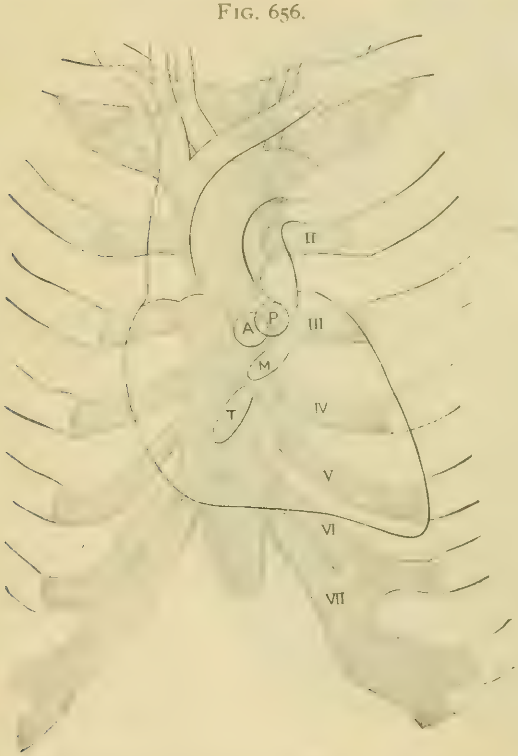


Posterior aspect of heart hardened in situ; showing lines of reflection of pericardium.

slightly flattened prolongations of the auricles, and bend forward around the bases of the aortæ, which they slightly overlap in front; they are the only portions of the auricles visible upon the anterior surface of the heart. Upon its superior surface the right auricle receives the termination of a large venous trunk, the *vena cava superior*, which returns to the heart blood from the head, neck, upper extremities, and walls of the thorax; while upon its posterior surface is the opening of another large vessel, the *vena cava inferior*, which returns blood from the abdominal and pelvic walls and viscera and from the lower limbs. The left auricle receives upon its surface the four *pulmonary veins* arranged in pairs, one pair situated towards the left portion of the auricle and the other towards the right.

Position.—The heart may vary considerably in position without being regarded as abnormal, but what may be considered its typical position with reference to the anterior thoracic wall may be stated about as follows: The *apex* is situated behind the fifth intercostal space, about 8 cm. ($3\frac{1}{4}$ in.) from the median line, this position being median to and slightly below the junction of the fifth costal cartilage with its rib. The *level of the base* may be approximately indicated by a line drawn from a point slightly above the upper border of the third costal cartilage of the left side, about 4.5 cm. ($1\frac{3}{4}$ in.) from the median line of the sternum, to a point upon the upper border of the third costal cartilage of the right side, about 3 cm. ($1\frac{1}{4}$ in.) from the middle line. If now the left end of the base-line be united to the apex point by a line which is slightly convex towards the left, and a line, markedly convex towards the right, be drawn from the right end of the base-line to the junction of the seventh costal cartilage of the right side with the sternum and thence to the apex point, a *heart-area* will be enclosed which corresponds to the outline of the organ as seen from in front.

Fig. 656.



Position of heart and valves in relation to anterior thoracic wall. A, aortic valve; P, valve of pulmonary aorta; T, tricuspid valve; M, mitral valve.

Considerable importance attaches to the location of the auriculo-ventricular and aortic orifices with reference to the anterior thoracic wall. The *right auriculo-ventricular orifice* in a typical heart lies on a level with the attachment of the fifth costal cartilages to the sternum, almost behind the median line of that bone and opposite the fourth intercostal space, while the *left auriculo-ventricular orifice* is opposite the sternal end of the left third intercostal space. In other words these openings lie along a line which corresponds with the auriculo-ventricular groove, and this may be represented by a line drawn from the upper border of the junction of the seventh costal cartilage of the right side with the sternum to the sternal end of the third left costal cartilage. The right orifice is located upon the line where it is intersected by a line joining the sternal ends of the fifth costal cartilages, while the left one is situated at its upper end.

The systemic and pulmonary aortic orifices are situated at about the level of the attachment of the third costal cartilages to the sternum, the *pulmonary orifice* being behind the sternal end of the third left cartilage, while the *aortic orifice* is behind the left half of the sternum, a little below and to the right of the pulmonary one, the two orifices overlapping for about one-quarter of their diameters. It is to be noted, however, that the pulmonary aorta is directed upward and to the left, while the systemic aorta inclines decidedly towards the right in the first part of its course; and since the sounds caused by the valves which guard the orifices are carried in the direction of the blood-stream, auscultation of the pulmonary semilunar valves may be practised over the sternal end of the second left intercostal space, while that of the systemic valves is best performed over the sternal end of the second right space.

Similarly the close proximity of the areas of the left auriculo-ventricular and systemic aortic orifices, as projected upon the thoracic wall, might lead to confusion,

were it not that the course of the blood passing through the two orifices is in opposite directions, and the auscultation of the auriculo-ventricular orifice is consequently satisfactorily performed towards the apex of the heart.

Considerable variation from the position of the heart indicated above may be found. Thus, the apex may be situated behind the fifth costal cartilage, or more rarely the sixth, and the pulmonary aortic orifice may occur as high up as the second intercostal space, or as low as the level of the fourth costal cartilage.

The heart naturally has its position altered somewhat during its contraction and during the respiratory acts, and the position of the body will also have some effect in modifying its location. Resting, as it does, upon the diaphragm, the heart will alter its position somewhat with alterations of that muscle; and since in the child the diaphragm is somewhat higher and in the aged somewhat lower than in the middle period of life, corresponding changes according to age will be found in the position of the heart. It may be noted, furthermore, that the position of the heart as determined in the cadaver will, as a rule, be slightly higher than in the living body, owing to post-mortem tissue changes which allow the diaphragm to assume a more vaulted form than is usual in life.

Relations.—As regards its relations the heart is completely enclosed within the pericardium, with which alone surrounding organs come into contact. In what follows it is really the relations of the pericardium that will be described, although of necessity these relations are indirectly those of the heart and will be spoken of as such.

Anteriorly the greater part of the heart is covered by the anterior borders of the lungs and pleuræ, which separate it from contact with the anterior thoracic wall. As a rule, the anterior borders of the pleuræ are in contact from the level of the second costal cartilage to that of the fourth, but below the latter level they separate, the border of the left pleura diverging from the median line more rapidly than that of the right. In consequence, throughout an irregularly triangular area (Fig. 1580), whose vertical diameter extends from the level of the fourth to that of the sixth costal cartilages, the heart is uncovered by the pleuræ and lies directly behind the thoracic wall. This area forms what is termed by clinicians the *area of absolute dulness*. *Laterally* the heart is in relation with the lungs, the phrenic nerves passing downward on either side between the pericardium and the pleura. *Posteriorly* the relations are again with the lungs and with the œsophagus and the thoracic aorta. *Inferiorly* the heart rests directly upon the diaphragm, beneath which is the stomach.

Size and Weight.—There is considerable individual variation in the size of the heart, and marked discrepancies exist in the observations that have been recorded. It may be said that in the adult the heart, on an average, will possess a length of from 12–15 cm. (4¾–6 in.), a greatest breadth of from 9–11 cm. (3½–4¼ in.) and a thickness of from 5–8 cm. (2–3¼ in.).

Its weight has been given at from 266–346 gm. (9⅜–12¼ oz.) for males and from 230–340 gm. (8⅛–12 oz.) for females, the average of a series of observations by different authors giving 312 gm. (11 oz.) for the male and 274 gm. (9¾ oz.) for the female. The proportion of heart to the weight of the entire body, according to an average drawn from several observers, is 1 : 169 in the male and 1 : 162 in the female. It must be remembered, however, that the weight of the heart increases with age up to about the seventieth year, probably a slight diminution taking place after that period.

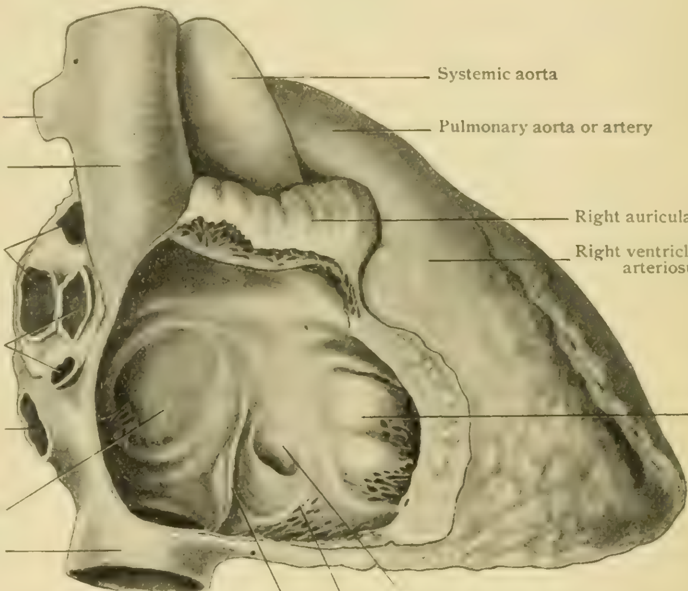
THE CHAMBERS OF THE HEART.

It has already been noted that the heart is composed of four chambers, a right and left auricle and a right and left ventricle. As the heart lies in position, little of the auricles, with the exception of the auricular appendices, can be seen, since they have in front of them the roots of the aortæ. In the ventricular portion the greater part of the anterior surface is formed by the right ventricle, a small portion only of the left ventricle showing to the left and at the apex, the whole of which is formed by the left ventricle. The four chambers will now be considered in succession, beginning with the auricles.

The Right Auricle.—The right auricle (atrium dextrum) is a relatively thin-walled chamber having in cross-section a roughly triangular form, the various sur-

faces, however, passing into one another almost insensibly without forming distinct angles. Viewed **externally**, the roof of the chamber is directed upward, backward, and somewhat to the right, and near its junction with what may be termed the posterior wall receives the superior vena cava. The posterior wall, also smooth and rounded, receives, near its junction with the median wall, the inferior vena cava, and below and to the left of this, in the posterior auriculo-ventricular groove, is the terminal portion of a vein which winds around the heart from the left and is termed the *coronary sinus*. The antero-lateral wall is prolonged into a somewhat triangular diverticulum with crenulated edges, which winds anteriorly around the proximal portion of the systemic aorta and is known as the *right auricular appendix* (**auricula dextra**). The median wall is not visible on surface view, and is formed by a rather thin muscular partition, the *auricular septum* (**septum atriorum**), which is common to both auricles; and the floor, also invisible from the exterior, corresponds to the base of the right ventricle, and is perforated by an oval aperture, the *right auriculo-ventricular orifice*, which places the cavity of the auricle in communication with that of the right ventricle.

FIG. 657.



Interior of right auricle exposed after removal of part of heart wall.

When the **interior** of the right auricle is examined (Figs. 657, 661), the surface is found to be for the most part smooth, being lined throughout by a delicate shining membrane covered by flattened cells and termed the *endocardium*. The general smoothness of the surface is, however, interrupted here and there by minute depressions (**foramina venarum minimarum**) into some of which open the orifices of *Thebesian veins* that traverse the walls of the heart. The cavity of the auricular appendix is crossed by a net-work of anastomosing fibro-muscular trabeculæ, the *musculi pectinati*, which are everywhere lined upon their free surfaces by endocardium and give to the appendix a somewhat spongy texture. In the roof of the auricle is seen the circular *orifice of the superior vena cava*, unguarded by valves and having a diameter of from 18–22 mm., and on the posterior wall is the somewhat oblique *opening of the inferior vena cava*, somewhat larger than that of the superior one, measuring from 27–36 mm. in diameter. The lower and lateral margins of this orifice are guarded by a crescentic fold, the *Eustachian valve* (**valvula venae cavae inferioris**), which tends to direct the blood entering by the vein upward and medially, and is the remains of a structure of considerable importance during fœtal life (page

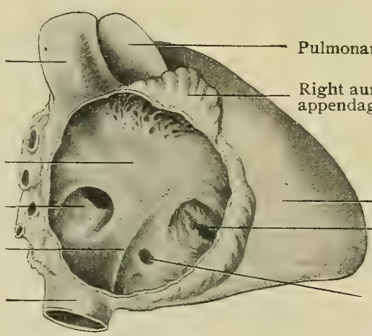
708). Between the superior and inferior venæ cavæ there may sometimes be seen a more or less marked prominence of the posterior wall, the *tubercle of Lower* (**tuberculum intervenosum**), the remains of a structure also of importance in the fœtal circulation. Below and somewhat median to the opening of the inferior vena cava is the circular *orifice of the coronary sinus*, measuring about 12 mm. in diameter, and guarded, like the inferior caval orifice, by a crescentic valve which surrounds its lateral margin and is termed the *Thebesian valve* (**valvula sinus coronarii**).

The median wall, in addition to a number of Thebesian orifices, presents at about its centre an oval depression, the *fossa ovalis*, whose superior and anterior borders are surrounded by a thickening or slight fold termed the *annulus ovalis* (**limbus fossae ovalis**).

The fossa ovalis indicates the position of what was in fœtal life the *foramen ovale*, through which the blood entering the right auricle from the inferior vena cava passed directly into the left auricle and so joined at once the systemic circulation (page 929). This foramen traversed the auricular septum obliquely, the septum really consisting of two folds, one of which projected backward from the anterior wall of the auricular portion of the heart, and the other forward from the posterior wall, the plane of the latter fold lying slightly to the left of that of the former one. After birth these two folds increase in size so that their free margins overlap and eventually fuse, closing the foramen, and the original free edge of the anterior fold becomes the annulus of Vieussens, while the floor of the fossa ovalis is formed by the posterior fold.

It occasionally happens that the foramen ovale fails to close after birth, remaining sufficiently open to permit of serious disturbances of the circulation which are usually, although not always, early fatal. Very frequently, however, the fusion of the overlapping surfaces of the two folds is not quite complete, and a small, oblique, slit-like opening persists between the two auricles. In such cases during the contraction of the auricles the pressure of the blood on the overlapping walls of the slit brings them into close apposition and effectually closes the slit, so that no disturbances of the circulation result from its presence. This slit-like opening has been found to be present in somewhat over 30 per cent. of the adult hearts examined.

FIG. 658.



Heart of fœtus just before birth; wall of right auricle has been cut away, showing foramen ovale.

The Left Auricle.—The left auricle (**atrium sinistrum**) has the same general external form as the right one, and, as in the latter, its antero-lateral wall is prolonged into an *auricular appendix* which curves forward around the left side of the proximal portion of the pulmonary aorta. Upon its posterior surface the auricle receives the four pulmonary veins arranged in pairs, one of which is situated nearer the medial and the other towards the lateral edge of the surface, and passing obliquely over this surface towards the coronary sinus is a small vein, known as the *oblique vein of the left auricle* (**vena obliqua atrii sinistri [Marshalli]**), which represents the proximal end of the left vena cava superior present during early embryonic life (page 927).

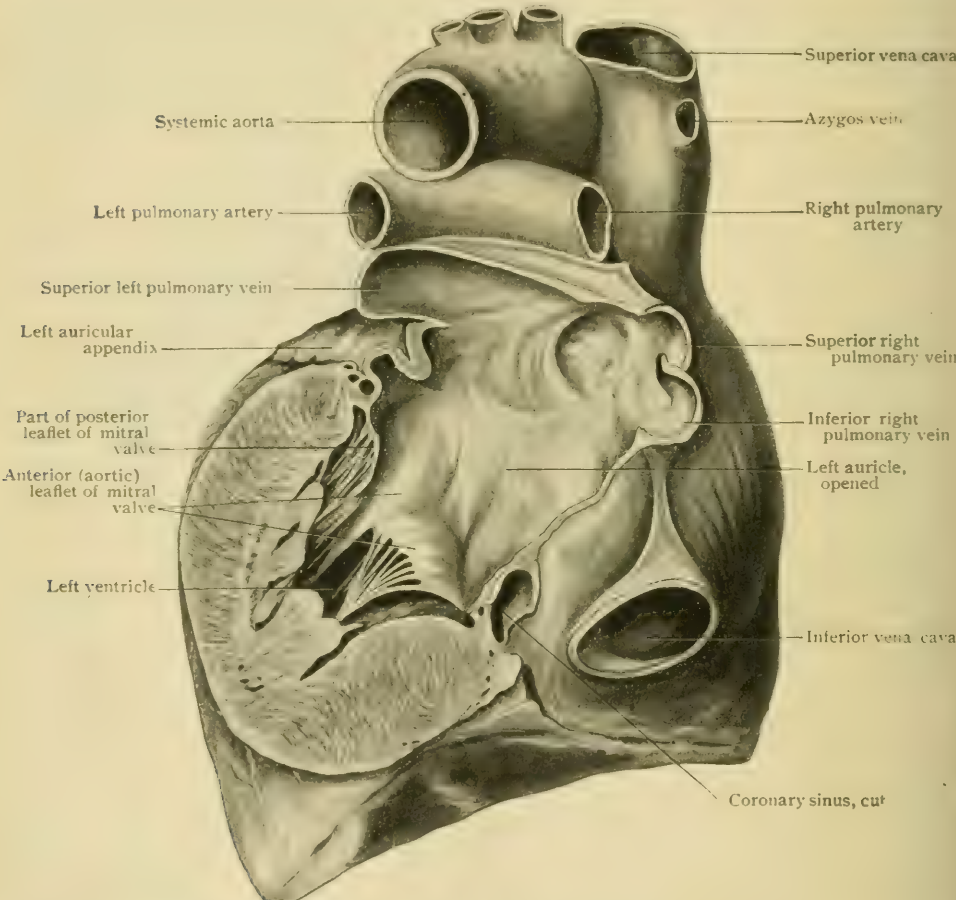
Viewed from the **interior,** the walls of the left auricle, like those of the right one, are everywhere lined by a smooth, shining endocardium; in the appendix the spongy structure due to the existence of anastomosing *musculi pectinati* also occurs, and occasional depressions of the surface mark the openings of *venæ Thebesii*, which are, however, much less abundant than in the right auricle. The *openings of the pulmonary veins* on the posterior wall are circular, and each measures from 14–15 mm. in diameter; they are unguarded by valves, although a slight horizontal fold separates the portion of the auricular cavity into which the left veins open from the entrance into the auricular appendix.

Upon the median wall, over the area occupied by the fossa ovalis of the right auricle, a slight depression is frequently to be observed, and immediately anterior to it there is usually a small crescentic fold, the *semilunar fold*, whose concavity is

directed forward, and which represents the free edge of the posterior segment or fold of the auricular septum (page 708). In the floor is situated the large circular *auriculo-ventricular orifice* by which the cavity of the auricle communicates with that of the left ventricle.

The Ventricles.—The two ventricles present many features in common and may be described together, such differences as exist between them being pointed out as the description proceeds. Each has a form which may be likened to a three-sided pyramid whose base is directed upward and the apex downward. The edges of the left ventricle are, however, somewhat more rounded than those of the right, so that its form approaches more nearly that of a cone; and, furthermore, it is somewhat

Fig. 659



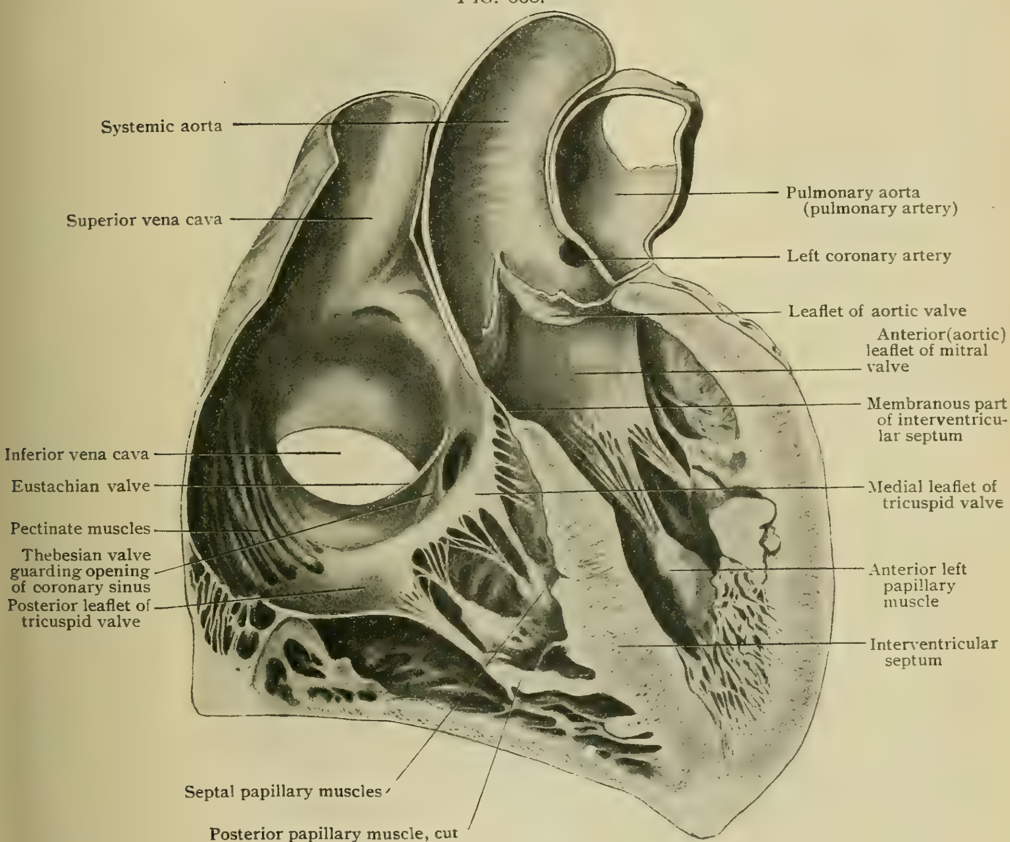
Interior of left auricle and ventricle, seen from behind; posterior wall of heart has been partially removed by frontal section.

longer than the right, its apex alone forming the apex of the heart. The surfaces presented by each ventricle may be termed antero-lateral, posterior, and median, but in using these terms the heart is to be regarded as placed so that its long axis is vertical; *in situ* the antero-lateral surfaces look largely upward and the posterior surfaces downward. The median wall is a partition, the *interventricular septum* (**septum ventriculorum**), common to the two ventricles, and completely separates their cavities. Throughout the greater part of its extent this septum is muscular, but towards its upper border it becomes fibrous (*pars membranacea*) and is continuous with the septum of the auricles; the position of its edges is indicated upon the external surface of the heart by the anterior and posterior interventricular grooves. The bases of

the ventricles are directed upward, backward, and to the right, and each is perforated by two orifices. One of these in each ventricle is the *auriculo-ventricular orifice*, while the other, in the case of the right ventricle, is the *opening of the pulmonary aorta*, and is placed in front and a little to the left of the auriculo-ventricular orifice upon the summit of a slight conical elevation of the base of the ventricle, termed the *conus arteriosus* or *infundibulum*. The second orifice of the left ventricle is the *opening of the systemic aorta*, and is situated in front and a little to the right of the corresponding auriculo-ventricular orifice, immediately adjoining it.

Compared with those of the auricles, the walls of both ventricles are very thick, that of the left especially so, being from two and a half to three times as thick as the right one. Unlike the auricles in another way, the inner surfaces of the ventricles.

FIG. 660.



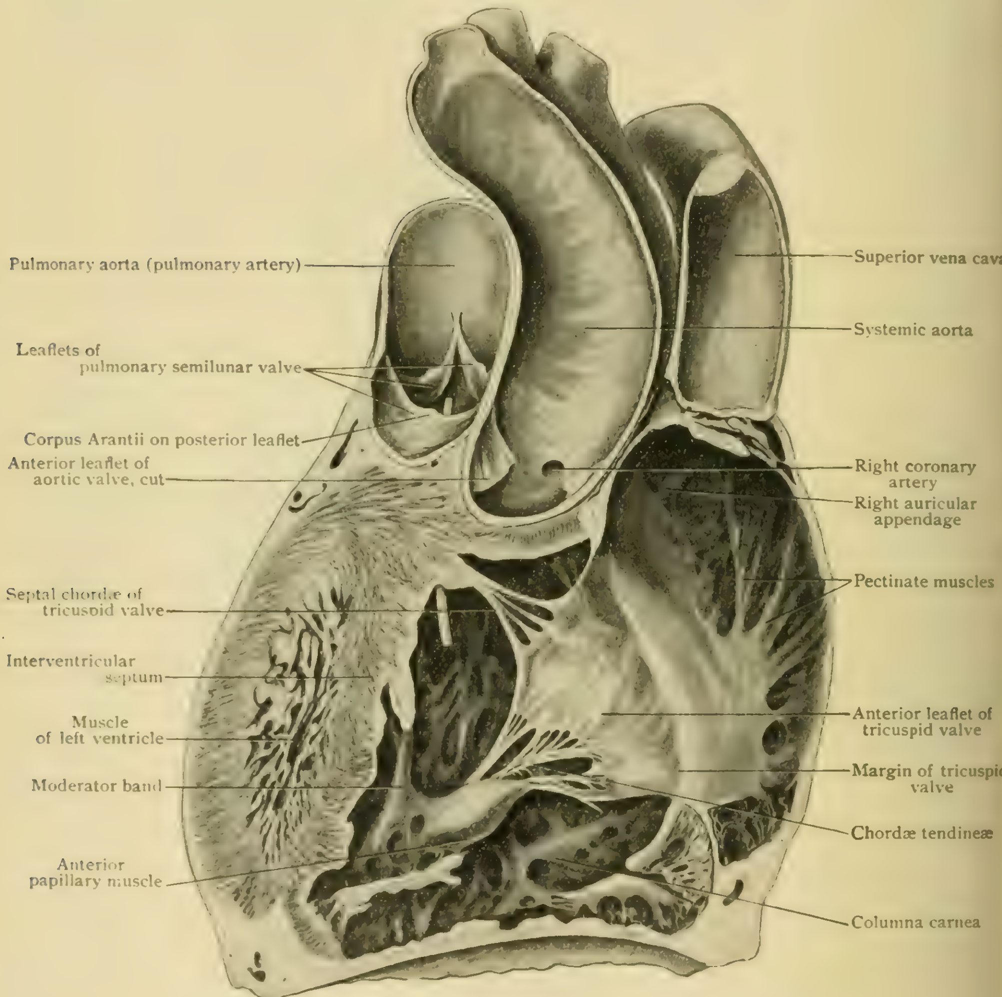
Posterior portion of heart, hardened in situ and sectioned parallel to posterior surface; viewed from before.

instead of being even, are very irregular, being everywhere covered by muscular ridges or columns, over and around which the endocardium is folded. These muscular elevations are usually regarded as consisting of three varieties: (1) ridges which are attached throughout their entire length to the wall of the ventricle, upon which they stand out like bas-reliefs; (2) columns which are attached at either extremity to the wall of the ventricle, but are free from it throughout the intervening portion of their length; and (3) columns which are attached only by one extremity to the ventricular wall and by their other extremity give attachment to slender tendons, *chordæ tendineæ*, which pass to the edges of the valves guarding the auriculo-ventricular orifices. To the columns belonging to the first and second of these groups the term *columnæ carneæ* is applied, while those of the third group are known

as the *musculi papillares*. Quite frequently in the right ventricle and more rarely in the left, a muscular band occurs, which passes across the cavity from one wall to the other near the apex; such a structure constitutes what has been termed a *moderator band*. Here and there between the columnæ carneæ of both ventricles minute orifices of the Thebesian vessels occur.

Around the orifices situated at the bases of the ventricles the muscular substance of the heart's walls passes over into dense fibrous tissue, of which the portion

FIG. 661.



Anterior wall of heart hardened in situ and sectioned parallel to posterior surface, viewed from behind; only very small part of left ventricle is seen; probe passes from pulmonary aorta (artery) into right ventricle.

surrounding the auriculo-ventricular orifices serves to connect the auricles and ventricles. If the auricles and the proximal portions of the aortæ be removed, the fibrous tissue will be seen to form four rings (**annuli fibrosi**), one corresponding to each of the basal orifices of the ventricles; and, furthermore, three of the rings—those surrounding the two auriculo-ventricular orifices and that of the systemic aorta—will be seen to be directly in contact, while the fourth—that surrounding the pulmonary aortic orifice—is separate from the others, although connected with the right auriculo-ventricular ring by a narrow fibrous band which descends in the posterior

wall of the conus arteriosus. The ring surrounding the left auriculo-ventricular orifice is somewhat thicker than that of the right, and is fused with the systemic aortic ring throughout about the medial third of its circumference, whereas the corresponding fusion of the right ring is of much less extent. In the angle formed by the junction of the right auriculo-ventricular ring at the side with the systemic aortic ring in front a special thickening of the fibrous tissue occurs, so that it becomes of almost cartilaginous consistency, and a similar, although smaller, thickening also occurs in the angle formed by the junction of the anterior walls of the left auriculo-ventricular and systemic aortic rings. These thickenings form what are termed the right and left *auriculo-ventricular nodes* (**trigona fibrosa**), and they are of interest as being occasionally the seat of a calcareous deposit or of a fatty infiltration, a condition which may be shared by fibre-like prolongations of the nodes (*fila coronaria*) which extend into adjacent portions of the auriculo-ventricular rings.

The Auriculo-Ventricular Valves.—Attached by its base to each auriculo-ventricular fibrous ring, and projecting downward into the cavity of the corresponding ventricle, is a valve having the general form of a membranous cone, whose walls are of thin but strong fibrous tissue covered on both sides by the endocardium. Each cone, however, is divided by deep incisions into triangular segments, of which there are three in the valve of the right ventricle, whence it is usually termed the *tricuspid valve*, while two incisions divide the left valve into two segments and procure for it the name of the *bicuspid* or *mitral valve*, the latter term being suggested by its resemblance to a bishop's mitre. Of the three segments of the **tricuspid valve**, one (**cuspis anterior**), larger than the others and also known as the *infundibular cusp* is attached to the anterior border of the auriculo-ventricular orifice ; a second one (**cuspis posterior**) is attached to the posterior border ; while the third or *septal* (**cuspis medialis**) occupies the interval between the medial edges of the other two, and is attached to that portion of the auriculo-ventricular fibrous ring which is united to the right auriculo-ventricular node and to the upper part of the ventricular septum. In the **mitral valve** one segment (**cuspis posterior**) is attached to the posterior border of the auriculo-ventricular fibrous ring, while the other (**cuspis anterior**) or *aortic cusp* is situated anteriorly, and depends from that portion of the ring which is united to the ring surrounding the systemic aortic orifice, and consequently appears to be a downward prolongation from the posterior border of that orifice. It is to be noted that the depths of the incisions separating the segments of both valves vary considerably, and additional incisions may occur, resulting in the formation of additional segments. Not infrequently a small accessory segment occupies the apex of one or more of the incisions.

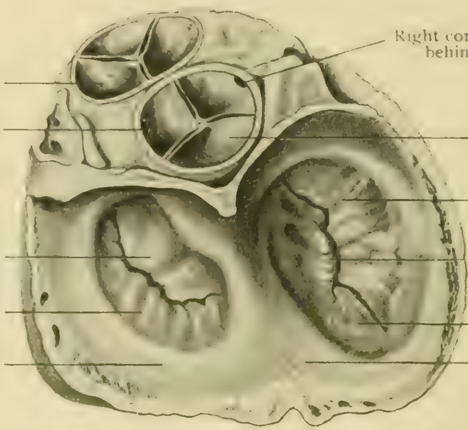
These valves, while permitting the free passage of blood from the auricles into the ventricles, prevent its passage in the reverse direction during the contraction of the ventricles ; for the pressure of the blood within the ventricles forces the segments upward so that they completely occlude the auriculo-ventricular orifices, the chordæ tendineæ which are attached to them, and which are rendered taut by the contraction of the papillary muscles, preventing them from being forced back into the auricles. The **musculi papillares** of each ventricle are arranged in two groups, one consisting of small papillæ, situated near the upper portion of the ventricle behind the segments of the valves, and the other, composed of larger conical muscles, situated nearer the apex. The **chordæ tendineæ** which arise from the upper group are short, and are attached to the ventricular surface of the valve near its base ; those which arise from the lower group are much larger, and are attached to the edges of the valve and to its ventricular surface near its free edge. The papillary muscles belonging to this lower group tend to be arranged in sets corresponding in position with the incisions which separate the segments of the valves, and there are, accordingly, three sets in the right ventricle and two in the left ; but this arrangement is not quite definite, and there is also considerable variation in the number of papillary muscles in each set, only one being present in some cases and several in others. However that may be, the chordæ tendineæ arising from the apices of the muscles of each set diverge as they pass upward and are attached to both the adjacent segments of the valve. When distinct accessory segments occur, they also receive the insertion of some of the chordæ tendineæ.

The Semilunar Valves.—Although really belonging to the pulmonary and systemic aortæ, it is convenient to consider these valves along with the heart, since they prevent the regurgitation of the blood contained in the aortæ into the ventricles at the completion of their contraction.

The segments guarding these valves are three in number in each aorta and are attached to the fibrous ring of the aortic orifices. Each segment is a crescentic pouch-like structure, whose cavity is directed away from the heart, so that any tendency for the blood to return from the aortæ into the ventricles will result in the filling of the pouches so that the three are brought into apposition and effectually close the orifice. Their efficiency is increased by (1) the occurrence at the middle of the free edge of each segment of a small fibro-cartilaginous nodule, the *nodule of Arantius*, which fills the small gap which might otherwise be left at the point of meeting of the free edges of all three segments; and by (2) the aorta being pouched out behind each segment to form a small pocket, a *sinus of Valsalva*, greater opportunity being thus allowed for the blood to enter the cavities of the valves and so force their free edges together.

The segments of the semilunar valves of the systemic aorta (**valvulae semilunares aortae**) are somewhat stronger than those of the pulmonary aorta (**valvulae semilunares a. pulmonalis**), and are arranged, if considered with reference to the planes of the body, the heart being *in situ*, so that one is situated anteriorly and the other two right and left posteriorly. In the pulmonary aorta one valve segment will be posterior and the others right and left anteriorly. If, however, the heart be held so that its ventricular septum lies in the sagittal plane, then the valve segments differ by 60° from the relative position given above, those of the pulmonary artery being arranged so that one lies anteriorly and the other two right and left posteriorly, while in the systemic aorta one is posterior and the other two right and left anteriorly, an arrangement to be expected from the manner of development of the valves (page 710).

FIG. 662.



Valves of heart viewed from above, after removal of auricles and greater part of aortæ.

The Architecture of the Heart Muscle.—The musculature of the **walls of the auricles** is relatively very thin, and it is difficult to distinguish any definite arrangement of its fibres in layers. Groups of fibers can, however, be distinguished, and of these certain are confined to each auricle, while others are common to the two.

Of the fasciculi proper to each auricle two principal groups can be recognized.

1. *Annular fasciculi*, which surround the orifices of the veins entering the auricles, and represent the continuation of the circular muscle layer of the veins into the auricular walls.

2. *Ansiform fasciculi*, which take their origin from the auriculo-ventricular fibrous ring anteriorly and extend over the auricle to insert into the fibrous ring posteriorly. These bundles are situated as a rule more deeply than the annular fasciculi and produce the pectinate muscles of the auricular appendage, as well as certain columnar elevations, covered by endocardium, which occur upon the inner surfaces of the walls of the auricles.

The fasciculi common to both auricles are developed only in the neighborhood of the auriculo-ventricular groove, and constitute thin superficial bands, which run parallel to the groove. The anterior fasciculus is broader and more highly developed than the posterior one.

The auriculo-ventricular fibrous ring forms an almost complete separation between the musculature of the auricles and that of the ventricles, the only direct connection between the two being formed by a slender *auriculo-ventricular fasciculus*. This takes its origin in the posterior wall of the right auricle close to the auricular septum (His, Jr.) and passes downward towards the upper border of the muscular portion of the ventricular septum (Fig. 663). Here it bends forward and runs across the septum in the line of junction of its membranous and muscular portions, and is lost anteriorly in the musculature of the ventricles. The existence of this auriculo-ventricular fasciculus is of considerable importance in connection with transmission of the contraction wave from the auricles to the ventricles, the application of a clamp to the bundle having been shown to produce heart-block (Erlanger).

FIG. 663.

Portion of left ventricle, showing position (+) of auriculo-ventricular muscle bundle in membranous part of interventricular septum. (*Retzer.*)

It can readily be perceived that the muscle-fibres of which the **walls of the ventricles** are composed are arranged in more or less definite layers, and that the direction of the fibres in the deeper layers is different from that of the more superficial ones. The descriptions of the various layers and of their relations to one another vary greatly in different authors; in that given here the results obtained by MacCallum, by the application of more suitable methods than were available to the earlier observers, will be followed.

FIG. 664.

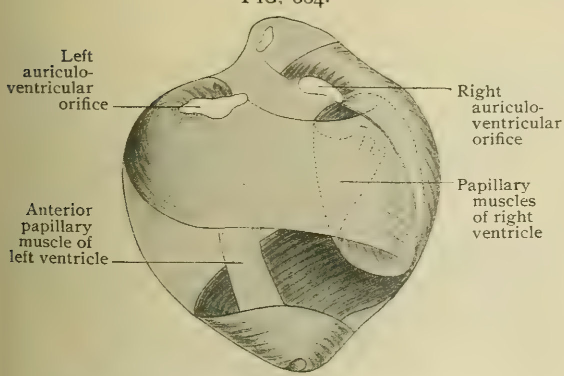


Diagram of course of superficial muscle layers originating in right and left auriculo-ventricular rings and in posterior half of tendon of conus arteriosus. (*MacCallum.*)

The fibres of the ventricles can start only from the fibrous rings surrounding the ventricular orifices or else from the summits of the musculi papillares, to which a certain amount of fixation is afforded by the chordæ tendineæ and their attachment to the auriculo-ventricular valves. It will be convenient to regard the fibrous rings as the principal points of origin, and the most *superficial layer* of the musculature may be said to arise from them and from the tendinous band which descends upon the posterior surface of the conus arteriosus towards the right auriculo-ventricular ring. Those fibres which take their origin from this tendinous band and the right ring wind in a left-handed spiral over the surface of the

ventricles, and when they reach the apex, they bend upon themselves and pass deeply and upward to terminate in the papillary muscles of the left ventricle. Those fibres which arise from the left auriculo-ventricular fibrous ring cross the posterior interventricular groove and, passing beneath the fibres from the right ring, encircle the right ventricle and finally terminate in the papillary muscles of that ventricle.

Fig. 665

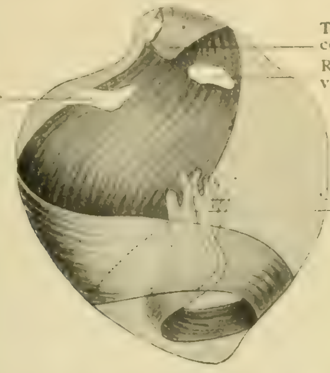


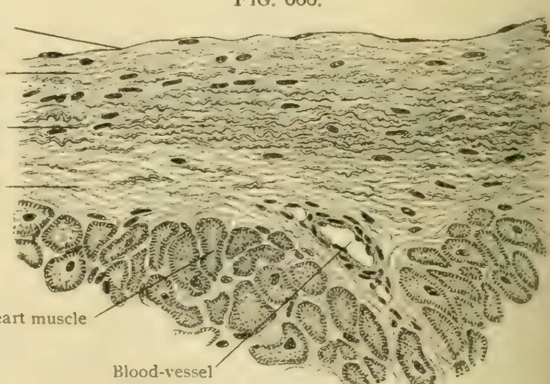
Diagram of course of superficial muscle layers originating in anterior half of tendon of conus arteriosus. (*MacCallum.*)

On the removal of these superficial fibres a deeper set is seen, which seem to form two muscular cones, each surrounding one of the ventricles. In the adult heart it is difficult to perceive the true relations of the two cones, but in the hearts of young individuals up to two or three years of age it has been found that both the cones are formed by the curving of a continuous sheet of fibres in an S-shaped manner. This *deep sheet* of fibres takes its origin principally from the right auriculo-ventricular fibrous ring and from the tendinous band of the conus arteriosus, and encircles the right ventricle, lying beneath the superficial layer. When it reaches the posterior border of the ventricular septum, it passes forward in that structure, and then encircles the left ventricle, terminating finally in the papillary muscles of that ventricle. The deep fibres which arise from the left fibrous ring are entirely confined to the left ventricle, forming a circular band surrounding its basal portion.

Structure.—The heart muscle, the *myocardium*, is both covered and lined with serous membrane, the *epicardium*, as the visceral layer of the pericardium is often called, investing it externally and the *endocardium*, continuous with the intima of the large blood-vessels, clothing all parts of its elaborately modelled inner surface.

The **epicardium** corresponds in its general structure with other parts of the pericardium, consisting, as do other serous membranes, of a single layer of endothelial cells that covers its free surface and rests upon a stratum of fibro-elastic connective tissue. The elastic fibrillæ are very fine and numerous and, immediately beneath the endothelium, form a dense net-work. When not separated from the muscle by subserous fat, as it conspicuously is in the interventricular and auriculo-ventricular grooves, the epicardium is intimately attached to the subjacent muscular tissue. The numerous branches of the coronary vessels, as well as the nerve trunks and the microscopic ganglia connected with the cardiac plexuses, lie beneath the epicardium or within its deepest layer.

Fig. 666.



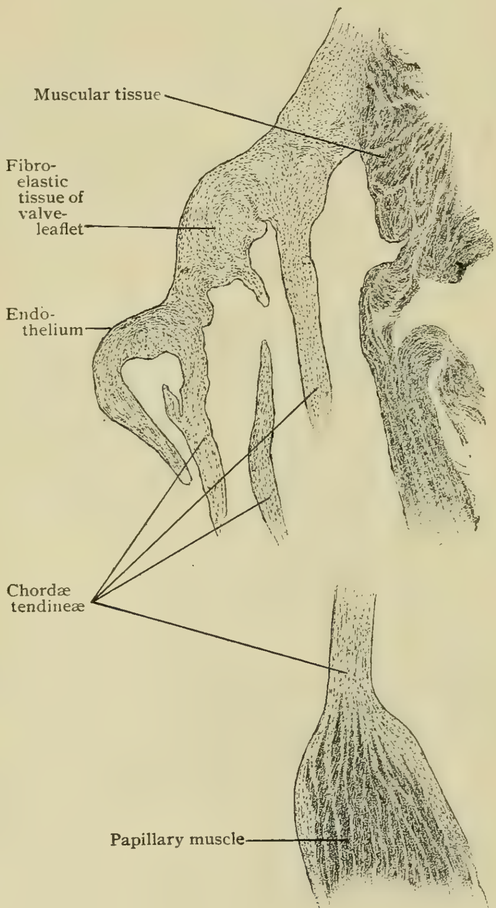
Section of endocardium. × 325.

The **endocardium** follows all the irregularities of the interior of the heart, lining every recess and covering the free surfaces of the valves, tendinous cords and papillary muscles. It consists of the endothelium and the underlying connective tissue. The latter is differentiated by the distribution

of the elastica into two strata, a thin subendothelial layer practically free from elastic fibres and a broad layer in which the elastica predominates. The deepest stratum of the endocardium is continuous with the endomysium that penetrates between the fibres of the heart muscle.

The **valves** consist of duplicatures of the endocardium, in their thicker parts strengthened by an intermediate middle layer of fibro-elastic tissue prolonged from the fibrous rings of attachment. Towards the free margins of the valves all three layers are blended and reduced to a thin fibrous stratum covered by endothelium. In the auriculo-ventricular leaflets, the fibro-elastic tissue of the chordæ tendineæ is continuous with the middle layer, while meagre peripheral bundles of muscle may be present beneath the endocardium. Although thinner than the auriculo-ventricular, the pulmonary and aortic semilunar valves possess essentially the same structure, the endocardial layer, however, being thickened to produce the noduli Aurantii.

FIG. 667.



Longitudinal section of leaflet of tricuspid valve. × 20.

In addition to the structural details of the fibres composing the myocardium already described in connection with the general histology of muscle (page 462), it may be noted that in the immediate vicinity of their nuclei the fibres of the heart-muscle constantly contain accumulations of undifferentiated sarcoplasm in which lie groups of highly refracting brownish granules that, under moderate magnification, appear as pigment at the poles of the nuclei. The muscle-fibres, branching into net-works with long narrow meshes, are held together by delicate lamellæ of connective tissue, the endomysium, which, together with the more robust septa that as the perimysium invest the muscular bundles, support the blood-vessels. The relation of the capillaries to the muscle-substance is unusually intimate, the capillary loops often modelling the surface of the fibres, lying in deep grooves almost completely enclosed by the surrounding sarcous tissue (Meigs). Although much less constant and typical than in the ventricular myocardium of many of the lower animals, as the sheep, goat, and ox, the imperfectly differentiated fibres, known as *fibres of Purkinje*, are represented in the human heart-muscle by subendocardial fibres. There is reason to believe that these fibres are related to the co-ordinating auriculo-ventricular bundle of His (page 701.)

The Blood-Vessels and Lymphatics of the Heart.—The heart receives its blood-supply through the two coronary arteries which arise from the systemic aorta immediately above its origin, the return flow being by the coronary veins which open into the right auricle by the coronary sinus. Both these sets of vessels will be described later (page 728), but it may be pointed out here that the branches of the coronary artery upon the surface of the heart are, as a rule, all end-arteries,—that is, arteries which form no direct anastomoses with their neighbors. Practically no blood can be carried directly, therefore, by the left coronary artery into the territory

supplied by the right one, or *vice versa*, and sudden occlusion of either of the arteries will produce serious disturbances or, in some cases, complete arrest of the contractions of the heart. Since, however, the capillaries of the heart's substance, into which each artery is continued, form a continuous net-work, a passage-way for the blood of one artery into the territory normally supplied by the other may be formed by their enlargement, opportunity for which may be afforded in cases in which the occlusion of an artery has been very gradual in its development.

There is, however, another way by which the tissue of the heart may receive nutrition in cases of gradual occlusion of the coronary arteries, namely, through the Thebesian orifices in the walls of the auricles and ventricles. These openings communicate by means of capillaries with the coronary vessels, and it has been shown experimentally that the heart can be effectively nourished by blood passing from the chambers of the heart through the Thebesian vessels and back into the coronary veins.

The **lymphatic vessels** of the heart form a net-work beneath the visceral layer of the pericardium, and a second less distinct net-work has also been described as occurring beneath the endocardium. These net-works communicate with two sets of principal vessels which lie in the anterior and posterior portions of the auriculo-ventricular groove. The *anterior set* passes from the right to the left, and, on reaching the pulmonary aorta, passes around its left surface to reach the systemic aorta, upon which it ascends to terminate in a lymphatic node situated to the left of the trachea. The *posterior set* opens in part into the anterior one and in part ascends along the right side of the pulmonary aorta to terminate in one of the nodes situated beneath the bifurcation of the trachea.

The Nerves of the Heart.—The nerves of the heart are derived from the cardiac plexuses and, passing downward along the aortæ, are distributed partly to the auricles and partly accompany the coronary arteries along the auriculo-ventricular groove, where they form the *coronary plexus*, from which branches are distributed to the ventricles. Over the surfaces of the auricles and ventricles the branches form a fine plexus situated beneath the visceral layer of the pericardium, and from this plexus branches pass into the substance of the heart to terminate upon the muscle-fibres. Some nerve-fibres are also distributed to the pericardium and endocardium, and these are regarded as being afferent in function, as are also certain fibres which terminate in the connective tissue of the heart's walls.

Scattered in the superficial plexuses there are numerous ganglion-cells, sometimes occurring singly and sometimes collected into small ganglia. They tend to be especially numerous around the orifices of the great veins opening into the auricles, in the coronary plexuses, and over the upper portions of the ventricles. It has been asserted that ganglion-cells also occur embedded in the walls of the ventricles, but at present this requires confirmation.

Much has yet to be learned concerning the qualities of the various nerve-fibres which pass to the heart in man, but it is presumable that they resemble in general those which have been determined experimentally for those of the lower mammals. In the latter it has been shown that the cardiac plexuses contain both afferent and efferent nerve-fibres. The cardiac plexuses are formed by branches from the pneumogastric and sympathetic nerves, and among the fibres from the former nerve are some which, when stimulated, cause a cessation of the heart's contractions, whence they are termed the *inhibitory nerves*. Stimulation of sympathetic fibres, which, in the dog, for example, pass to the cardiac plexus from the first thoracic ganglion of the ganglionated cord, produces an increase in either the rapidity or the intensity of the heart-beat, and these fibres are consequently termed the *accelerator* or *augmentor fibres*. Both the inhibitory and augmentor fibres are efferent,—*i.e.*, they carry impulses from the nerve-centres out to the heart; in addition, the existence of afferent fibres has been determined among the pneumogastric constituents of the plexuses. These are the *depressor fibres*, so called because their stimulation produces a marked fall in the blood-pressure, not on account of any action upon the heart-beat, since they lead the stimulus away from the heart, but by acting reflexly upon the intestinal vessels so as to produce their dilatation and, by thus lessening the peripheral resistance against which the heart must contend, lessen the work which the organ has to do.

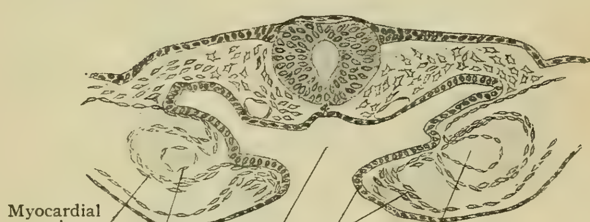
Whether the various efferent fibres pass directly to the muscular tissue of the heart or terminate upon cardiac ganglion-cells which transmit the impulse to the muscle-fibres is a point which remains to be determined, although, from analogy with what is known as to the relation of the cerebro-spinal fibres to other portions of the involuntary muscular tissue, it would seem probable that the pneumogastric efferent fibres terminate primarily upon the cardiac ganglion-cells.

DEVELOPMENT OF THE HEART.

In the mammals in which the earliest stages in the development of the heart have been observed, this organ arises as two separate tubes that are formed by folding of the visceral mesoblast near the margin of the embryonic area. This folding occurs while the embryo is still spread out upon the surface of the yolk-sac and produces on each side an elevation, a heart-tube, that projects into the primitive body-cavity (Fig. 668). Each heart-fold differentiates into a thicker outer or *myocardial layer*, which gives rise to a portion of the cardiac muscle, and a very thin inner *endocardial layer*, from which the serous lining of the heart is derived. The latter consists of a single stratum of mesoblastic cells surrounded by the muscle-layer, but separated by a distinct space, as a shrunken cast lies within its mould.

With the beginning constriction of the gut-tube from the vitelline sac and the associated approximation of the splanchnopleura of the two sides, the heart-tubes, at first widely apart, gradually approach the mid-line until they meet beneath the ventral surface of the primitive pharynx, in advance of the yolk-sac. Upon coming into contact, the cavities of the two heart-tubes for a brief period remain separated by the partition formed by the opposed portions of the myocardial layers. Very soon, however, solution of this septum occurs and the two sacs become a single heart. The endothelial tubes are last to fuse, retaining their independence after the myocardial walls have blended. Upon fusion of the endothelial layers the conversion of the double tubes into a single heart is complete.

FIG. 668.



Transverse section of very young rabbit embryo, showing two heart-tubes widely separated by unclosed digestive tube. × 150.

The early venous trunks —the body-stems (cardinals and jugulars) within the embryo and the vitelline and allantoic (later umbilical) veins from the extra embryonic vascular net-works—converge towards a common sac, the *sinus venosus*, which joins the caudal end of the cylindrical primitive heart. The slightly tapering cephalic extremity of the latter becomes the *truncus arteriosus*, from which two trunks, the *ventral aortæ*, are prolonged forward beneath the primitive pharynx, giving off the aortic bows that traverse in pairs the series of visceral arches. The primitive heart consists, therefore, of a cylinder, somewhat contracted at its anterior end, that occupies the ventral mid-line in the later cervical region. The blood poured into the sinus venosus by the veins enters its posterior extremity and escapes anteriorly through the truncus arteriosus.

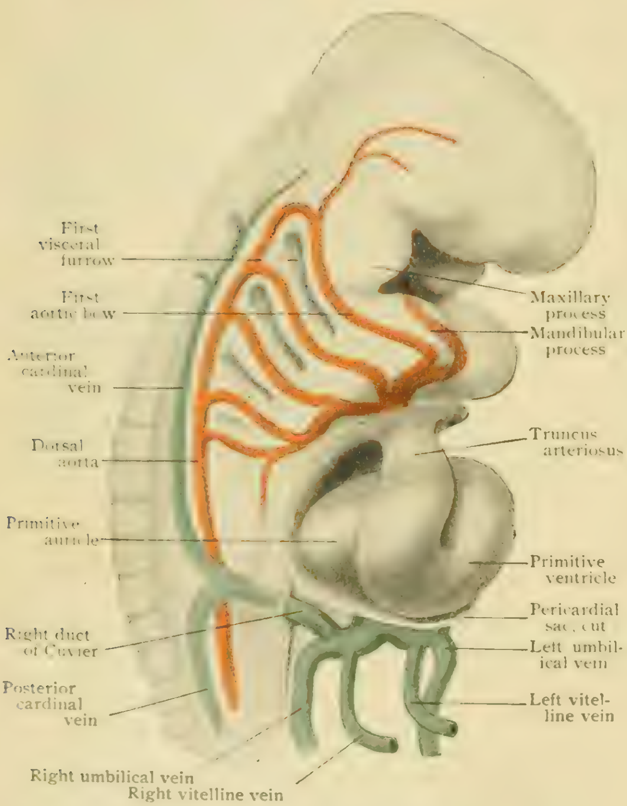
Although for a brief period the heart-tube retains its median position and straight cylindrical form, its increasing length soon causes it to become bent upon itself and to assume the S-like contour shown in Fig. 672 *A*, from an embryo of 2.15 mm. in length, in which the venous end of the tube lies below and to the left and the arterial trunk above and to the right. The intermediate portion of the tube, extending at first downward and then obliquely upward and towards the left, is the primitive ventricle, the early sigmoid heart-tube already suggesting the recognition of an arterial, ventricular, and venous segment.

During the further development of the heart a rearrangement of these three divisions takes place, since the venous segment, orginally below, gradually acquires a position above and behind, while the primitive ventricle comes to lie in front and below (Fig. 672). With the completion of this rotation, a deep external groove appears between the ventricular and venous chamber, now the *primitive auricle*, that indicates the position of a contracted passage, the *auricular canal* (Fig. 672, *C*), as the common auriculo-ventricular opening is termed. Coincidently with the upward migration of the venous segment, a lateral outpouching of the auricular chamber appears on each side of the truncus arteriosus. These expansions, the primary *au-*

ricular appendages, rapidly increase, until they form the most conspicuous part of the young heart (Fig. 673, *C*), embracing the upper part of the truncus arteriosus and overlying the ventricle.

Meanwhile the ventricular segment has assumed the most dependent and ventral position, for a time appearing as a transversely expanding sac (Fig. 672, *B*) that in form recalls a greatly dilated stomach, the truncus arteriosus joining the "pylorus," and the contracted auricular canal suggesting the œsophagus. Soon, however, the higher right end of the ventricular segment sinks to the level and gains the ventral plane of the left end, the ventricle in consequence losing in width but gaining in height. A shallow longitudinal crescentic furrow, the later *interventricular groove*, now appears on the surface of the ventricle and suggests the subdivision of this segment into right and left chambers, at the same time indicating the position of the growing internal partition that leads to this separation.

Fig. 669.



Reconstruction of upper part of human embryo of third week (3.2 mm.), showing relation of heart and blood-vessels. × 50. (*Drawn from His model.*)

Sections of the young heart (Fig. 670) show the venous and ventricular segments as widely communicating portions of the sigmoid tube, the walls of which are composed of the myocardial and endothelial layers. In somewhat older embryos (Fig. 671), the communication between these divisions of the heart-tube exhibits a slight contraction, marking the position of the later auricular canal, which becomes a narrow transverse cleft that connects the primitive ventricle with the auricular chamber. The myocardial layer of the heart-wall, particularly in the ventricle, also shows the beginning of the trabeculæ that invaginate the endothelial lining and eventually lead to the conspicuous modelling of the interior of the adult heart.

Frontal sections of the young human heart (Fig. 674, *A*) show the commencing separation of the ventricular and auricular chambers into right and left halves. This division is effected by the formation of a vertical partition consisting of an upper auricular, a middle valvular, and a lower ventricular part, supplemented by the aortic septum that appears in the truncus arteriosus and subdivides the latter into the pulmonary and systemic aortæ.

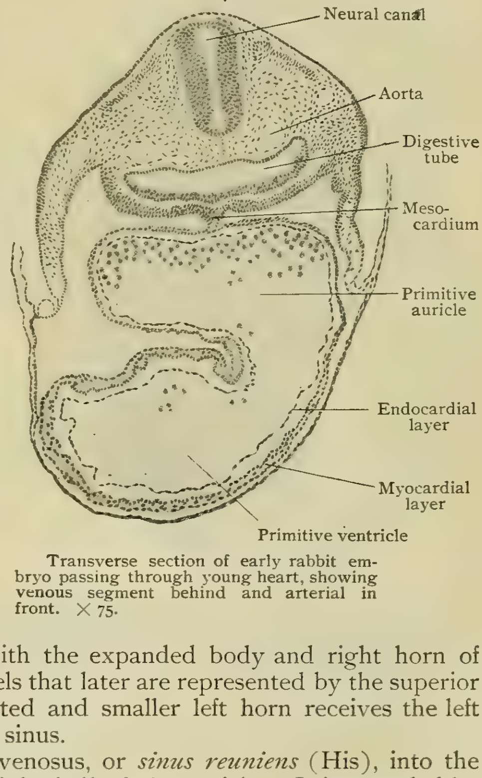
The subdivision of the auricle, which anticipates that of the ventricle, begins in the fourth week with the downward extension of a crescentic fold, the *auricular septum*, or *septum primum*, that gradually grows from the postero-superior wall of the auricle towards the auricular canal and fuses with the partition that, as the *septum intermedium*, is formed within the canal by local thickening of its anterior and posterior lips. In this manner not only the common auricular chamber, but also the transversely elongated auriculo-ventricular opening, is separated into a right and a

left half. The interauricular partition, however, is not complete, since an opening appears in its upper part even before it has finished its downward growth and union with the valvular septum. This opening enlarges and remains as the *foramen ovale* that persists until birth as a direct passage for the blood from the right into the left auricle during the continuance of the fœtal circulation (page 929).

The subdivision of the ventricular chamber, which commences a little later than that of the auricle, is accomplished chiefly by the formation of the *ventricular septum.* The latter grows from the postero-inferior wall of the ventricle as a crescentic projection that continues inward, a thickening of the ventricular wall corresponding in position with the external interventricular groove. The partition thus formed extends towards the auriculo-ventricular opening, where it meets and fuses with the septum intermedium, in this manner insuring the communication of the right and left auricles with the corresponding ventricles through the intervening respective portions of the valvular opening.

The isolation of the two ventricles from each other, however, is not at first complete, owing to the ventricular partition being imperfect above and in front. This deficiency is overcome by the downward extension of the *aortic septum* within the bulbus arteriosus (as the somewhat dilated lower end of the truncus arteriosus is now appropriately called) until it meets and fuses with the ventricular partition, thus completing the separation of the cardiac chambers into a right and left heart. The part of the ventricular partition contributed by the aortic septum always remains thin and constitutes the *pars membranacea* of the adult organ.

FIG. 670.



Transverse section of early rabbit embryo passing through young heart, showing venous segment behind and arterial in front. × 75.

Coincidently with the foregoing changes, the auricles undergo important modifications in their relations with the blood-vessels opening into them. During the development of the auricles, the oval *sinus venosus*, into which is conveyed the blood returned by the vitelline, allantoic (umbilical) and body-veins, elongates transversely into a crescentic sac, the convexity of which is in contact with the back of the auricles, its opening into the latter having shifted so that it is in relation with only the right half of the auricular chamber. With the expanded body and right horn of the venous crescent communicate the vessels that later are represented by the superior and inferior venæ cavæ, while the elongated and smaller left horn receives the left duct of Cuvier that becomes the coronary sinus.

For a time the opening of the sinus venosus, or *sinus reuniens* (His), into the heart occupies the posterior wall of the right half of the auricle. It is guarded by the *venous valve*, consisting of a right and left leaflet, that is prolonged forward along the roof of the auricle as a crescentic ridge, the *septum spurium* (Fig. 674, *A*). With the continued appropriation of the venous sinus by the expanding auricle, the single aperture of the sinus disappears as the sac becomes part of the auricular chamber, thereupon the two venæ cavæ and the coronary sinus open directly into the right auricle by an independent orifice. That of the superior cava lies in the upper posterior part of the auricle, that of the inferior cava being lower and more lateral, with the smaller orifice of the coronary sinus slightly below. The septum spurium, the greater part of the left, and the upper part of the right segment of the arching fold that originally surrounds the opening of the sinus venosus disappear during the appropriation of the venous sac by the auricle. The lower part of the right leaflet,

on the contrary, persists and differentiates into the larger *Eustachian valve*, that guards the lower margin of the inferior vena cava and directs its blood-stream towards the foramen ovale, and the smaller *Thebesian valve*, that protects the orifice of the coronary sinus.

As above noted, the separation of the two auricles is incomplete on account of the existence of the foramen ovale within the interauricular partition. From the roof and anterior wall of the right auricle an additional and relatively thick crescentic ridge, the *septum secundum*, arches around the foramen ovale of which it forms the anterior or ventral boundary. It lies close to and parallel with the auricular septum and fuses below with the lower part of the left segment of the venous valve to form the *limbus Vieussenii* that later limits the fossa ovalis, marking the former position of the foramen ovale. The latter, therefore, is included between two partially overlapping crescentic margins, that contributed by the septum auriculum lying behind and to the left, and that by the septum secundum in front and to the right, a narrow sagittal cleft intervening so that the surfaces of the lunate borders are not in contact.

Fig. 671.

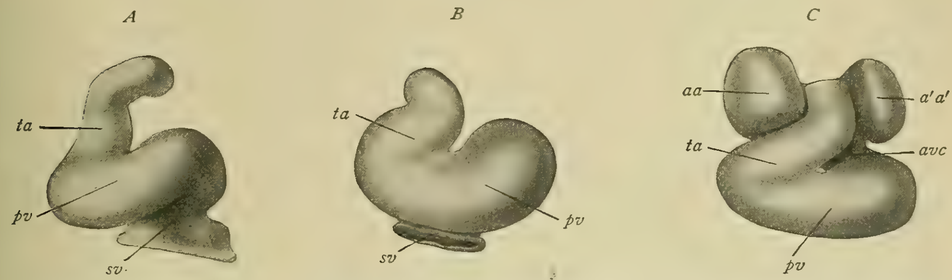
Transverse section of somewhat older embryo, showing differentiation into auricles, ventricle and truncus arteriosus. × 75.

Since the division of the heart into a right and left side is inseparably connected with the development of the lungs and the consequent necessity for a distinct pulmonary circulation, provision for the return of the blood from the lungs to the heart is made by the early formation of the *pulmonary veins*. These arise in pairs, one pair for each lung; close to the heart each pair unites into a single right or left stem that, in turn, joins with its fellow of the opposite side to form one short common trunk. For a time none of these vessels communicate with the heart, but later the common single pulmonary vein opens into the left auricle close to the septum. With the subsequent growth and expansion of the auricles an appropriation occurs on the left side similar to that affecting the sinus venosus on the right, in consequence of which the short common pulmonary vein is first drawn into the heart, to be followed next by the two secondary and, finally, by the four primary pulmonary veins, all of which then open by separate orifices into the enlarging left auricle. The frequent variations in the number of the pulmonary veins and in their relations to the heart are usually to be referred to arrest or modification of this fœtal appropriation.

The differentiation of a right and left *auriculo-ventricular valve* proceeds from the subdivision of the auricular canal by the septum intermedium. The latter is formed by the approximation and union of the median cushion-like projections upon the ventral and dorsal walls of the common auriculo-ventricular opening. The unobliterated lateral portions of the latter are triangular in outline and guarded by proliferations of the endocardium. Those of the lower margins of the valves elongate and project into the ventricles on the right side, giving rise to two leaflets, and on the left to a single flap. An additional prolongation from the partition contributes a septal leaflet on each side. In this manner the complement of flaps for the tricuspid and bicuspid (mitral) valves is early provided. The close relation between the leaflets and the attached restraining bands, the chordæ tendineæ, results from the secondary union of the immature flaps with the trabeculæ of the spongy myocardium of the young heart. The loose muscular walls undergo partial consolidation, so that

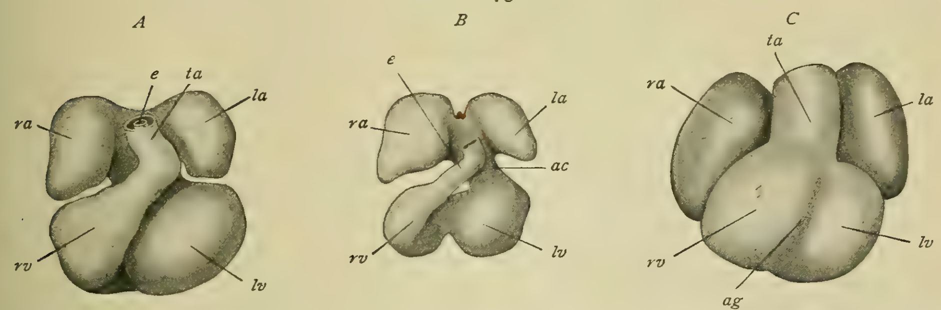
the outer strata of the ventricular muscle become compact while the inner layers for a time retain their characteristic trabeculæ. Those attached to the valves undergo thickening and consolidation and become the papillary muscles; a few persist as ties

FIG. 672.



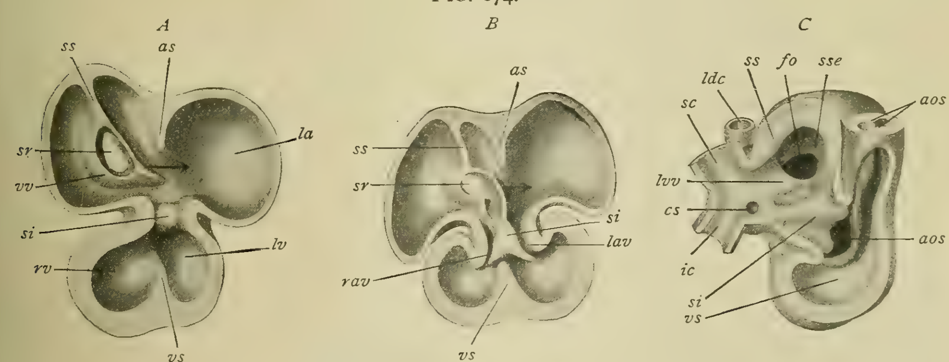
Reconstructions of developing hearts; *A*, from human embryo of about 14 days (2.15 mm. long); *B*, of 21 days (4.2 mm.); *C*, of 23 days (4.3 mm.); *ta*, truncus arteriosus: *pv*, primitive ventricle; *sv*, sinus venosus; *aa*, *a'a'*, right and left auricular appendages; *avc*, auriculo-ventricular canal. × 20. (*Drawn from His models.*)

FIG. 673.



Reconstructions of developing hearts; *A*, from human embryo of 25 days (5 mm. greatest length); *B*, endothelial heart from same; *C*, of 35 days (13.7 mm.); *ra*, *la*, right and left auricles represented by large auricular appendages; *rv*, *lv*, right and left ventricles; *ta*, truncus arteriosus; *e*, endothelial tube; *ac*, auriculo-ventricular canal; *ag*, interventricular groove. × 20. (*Drawn from His models.*)

FIG. 674.



Reconstructions of developing hearts; *A*, posterior half of heart of human embryo of 30 days (10 mm.) seen from in front; *B*, same from embryo of 35 days (*C* in preceding figure); *C*, same heart opened on right side showing imperfect septa; *as*, auricular septum; *vs*, ventricular septum; *ss*, septum spurium; *sr*, sinus reuniens; *vv*, venous valve; *si*, septum intermedium; *rv*, *lv*, right and left ventricles; *la*, left auricle; *rav*, *lav*, right and left auriculo-ventricular valves; *fo*, foramen ovale, occupied in *A* and *B* by arrow; *sse*, septum secundum; *lvv*, left leaflet of venous valve; *sc*, *ic*, superior and inferior vena cava; *cs*, coronary sinus; *ldc*, left duct of Cuvier; *aos*, aortic septum in truncus arteriosus. × 20. (*Drawn from His models.*)

or moderator bands; while the majority retain their freedom to a lesser degree and, as the columnæ carneæ, produce the conspicuous modelling of the interior of the ventricles. The muscular tissue, which at first extended to and even within the valve-

leaflets, subsequently undergoes partial atrophy and disappears from the flaps and adjoining parts of the attached bands, the latter thereby being converted into the fibrous chordæ tendineæ.

Even before the longitudinal subdivision of the bulbus arteriosus occurs, the junction of this tube with the primary ventricle is marked by four cushion-like thickenings that project from the interior of the bulb. These elevations, which consist of immature connective tissue covered by endothelium, furnish the leaflets of the aortic and pulmonary *semilunar valves*. The formation of the aortic septum within the bulbus arteriosus begins some distance above the valve and immediately below the origin of the right and left pulmonary arteries. From this point the partition gradually grows downward until it encounters the elongated lateral pair of the original four valve-cushions, of which one lies in front, one behind, and two at the sides of the bulb. With the completion of the division of the bulbus arteriosus into the systemic and pulmonary aortæ, the septum cleaves the two lateral cushions, each of the resulting valves being guarded by three leaflets so disposed that the original and undivided flap of the pulmonary artery lies in front, and that of the aorta behind. The partial rotation that later places the aortic valve behind and to the left of the pulmonary brings about the disposition observed in the adult (page 700), in which the single leaflet of the aortic semilunar valve lies in front and that within the pulmonary artery is behind. At first comparatively thick, the leaflets suffer partial absorption, whereby they are converted into the membranous cusps that bound crescentic pouches, the sinuses of Valsalva, which lie between the leaflets and the wall of the vessels.

PRACTICAL CONSIDERATIONS: THE HEART.

It is possible here only to indicate with great brevity certain changes in the position of the heart which should be studied in connection with its relations.

The apex beat, normally to be found about one inch below and two inches to the sternal side of the left nipple, is due to the recoil of the left ventricle as it empties its contents into the aorta, to the lengthening of that vessel as the blood enters it, to the consequent straightening of the arch (carrying the heart forward), and to the absence of any interposed lung-tissue over the "area of absolute dulness."

The apex beat (and usually the heart itself) is (*a*) *raised* in cases of ascites, tympanites, large abdominal tumors, and atrophic pulmonary conditions; (*b*) *depressed* in aortic aneurism, mediastinal growths, pulmonary emphysema, pleural effusion, and hypertrophy or dilatation of the left ventricle; (*c*) *displaced laterally to the right* by left pleural effusion, splenic tumors, hypertrophy of the right ventricle, *to the left* by hepatic tumors, right pleural effusion, hypertrophy of the left ventricle. The heart may be drawn to either side by contracting pleural adhesions. As the area of absolute dulness—"superficial cardiac area"—corresponds to that portion of the cardiac substance which is not separated by pulmonary tissue from the thoracic wall, it follows that its extent varies inversely with the size or expansion of the lungs. In emphysema the area of cardiac dulness may quite disappear; in the later stages of fibroid phthisis it may be much larger than normal.

In relation to the anatomy of the valves and cavities of the heart, the sounds produced by the passage of blood through them should be considered in connection with at least a few of the modifications caused by the chief pathological changes that affect that organ. It may be said here, for the sake of clearness, that the *first sound* occurs during the contraction of the ventricles, when the auriculo-ventricular openings should be closed by the mitral and tricuspid valves and the aortic and pulmonary orifices should be open, and that it is due to (*a*) the shutting of the valves, and (*b*) the impulse of the apex against the thoracic wall, with possibly some addition from (*c*) the contraction of the walls of the ventricles, although this latter factor is doubtful.

The *second sound* occurs during the auriculo-ventricular dilatation, and is due to the closure of the pulmonary and aortic semilunar valves caused by the recoil of the blood-current brought about by the elastic coats of the aorta and pulmonary arteries.

If a murmur heard over the chest is synchronous with the radial pulse (systolic), it occurs during ventricular contraction, and is usually due either (*a*) to regurgita-

tion of blood through an auriculo-ventricular valve that does not accurately close the corresponding opening or (*b*) to an obstruction to the exit of blood from the ventricle at the aortic or at the pulmonary orifice.

If a heart murmur is not synchronous with the radial pulse (diastolic or presystolic), it may be caused by (*a*) obstruction to the passage of blood from an auricle into a ventricle (mitral or tricuspid stenosis); or (*b*) regurgitation from the pulmonary artery or aorta into the right or left ventricle (pulmonary or aortic insufficiency).

Of these various murmurs those due to mitral and aortic insufficiency are by far the most frequent.

Valvular disease of the left side of the heart (90 per cent. of all cases) is more frequent on account of the greater work required of this side and the associated greater liability to strain, rarely sudden, usually trifling but oft repeated.

1. *Mitral insufficiency*—an imperfect closure of the segments of the left auriculo-ventricular valve—causes a systolic murmur, heard best (*a*) over the apex and superficial cardiac area because there the ear can most nearly approach the left ventricle without the interposition of pulmonary tissue or of the right ventricle; (*b*) in the axilla, because it is transmitted in the direction of the arterial blood-current; and (*c*) at the angle of the left scapula, or between the fifth and eighth thoracic vertebræ, for the same reason, and because at that point the left ventricle is posterior. In addition, the pulmonary second sound is louder and sharper than natural (accentuated) because of the following series of occurrences which should be studied in connection with the structures and cavities involved: over-filling and distention of the left auricle, imperfect emptying of the pulmonary veins, pulmonary congestion and resistance to the systole of the right ventricle, increased fulness of the pulmonary arteries, and corresponding increase of the backward pressure upon the pulmonary valves, shutting them more sharply and forcibly (accentuation).

Furthermore, as the distention of both ventricles results in hypertrophy, the transverse diameter of the area of cardiac dulness is distinctly increased.

2. In *mitral stenosis* (often associated with some degree of mitral insufficiency) a murmur is usually heard, preceding the pulse-beat (presystolic),—corresponding, that is, to the auricular systole, and, as the left auricle is distended—from imperfect emptying—and hence the pulmonary veins and arteries and the right heart are in the same condition, there is again a loud accentuation of the second sound.

3. *Aortic insufficiency* is characterized by a murmur that follows the radial pulse (diastolic), occurs as the blood is being driven back into the ventricle by the elastic aorta, is heard best over the sternal end of the second right intercostal space (*vide supra*), is often propagated towards the xiphoid cartilage or down the left side of the sternum, and is more rarely heard in the carotid or axillary vessels,—*i.e.*, as it is a murmur primarily due to the reflux of blood from the aorta into the ventricle, it is, in accordance with well-known laws of physics, transmitted in the direction of the current causing it.

The great distention and subsequent hypertrophy of the left ventricle caused by its inability to empty itself result in a marked increase of percussion dulness. As the aortic valves do not come together normally, the aortic second sound is feeble or absent.

4. *Aortic stenosis* (much less frequent than insufficiency) is usually accompanied by a systolic murmur heard at the aortic cartilage and transmitted along the great vessels to the axilla, to the neck, and along the spine, but difficult to distinguish from similar murmurs caused by disease of the inner coat of the aorta or by mere roughening of the valves. As the aorta receives a diminished quantity of blood, one factor in the production of the apex beat is lessened in effectiveness and the cardiac impulse is often also lessened. Dilatation and hypertrophy of the left ventricle with subsequent secondary changes in the other cavities may follow, but are not nearly so marked as in aortic insufficiency.

Valvular disease of the right side of the heart may, on account of its relative infrequency and to avoid repetition, be even more briefly summarized:

1. *Tricuspid insufficiency*—often following pulmonary conditions obstructing the circulation—is characterized by (*a*) a low systolic murmur heard well over the

lower sternum on account of the relation of the right auriculo-ventricular orifice to the middle of that bone ; (*b*) increase of percussion area to the right of the sternum because of the distention and dilatation of the right auricle that follow ; and, (*c*) from the same cause and the resultant backward pressure on the systemic veins, a venous pulse-wave, seen best in the internal and external jugular on the right side, but not infrequently recognizable on both sides, in the subclavian and axillary veins also, or as a systolic expansile impulse in the liver transmitted through the inferior cava and hepatic veins.

2. *Tricuspid stenosis*, like that of the mitral valve, is apt to cause a presystolic murmur, and for the same physical reasons.

3 and 4. *Pulmonary insufficiency and stenosis* (disease of the pulmonary valves) are so rare and so uncertain in their physical signs as to require mention merely to complete the survey of the group.

The various forms and degrees of *hypertrophy* or *dilatation* of the heart which are associated with the foregoing conditions can be readily understood by considering the increased resistance and correspondingly increased exertion which are brought about by the valvular changes. The essential cause of hypertrophy in the heart, as in other muscles, is increased work. The etiological factors which necessitate this should be studied in connection with the anatomy of the heart and have been well summarized by Osler.

Hypertrophy of the left ventricle alone, or with general enlargement of the heart, is brought about by—

(*a*) Conditions affecting the heart itself : (1) Disease of the aortic valve ; (2) mitral insufficiency ; (3) pericardial adhesions ; (4) sclerotic myocarditis ; (5) disturbed innervation with overaction, as in exophthalmic goitre, in long-continued nervous palpitation, or as a result of the action of certain articles, such as tea, alcohol, and tobacco. In all of these conditions the work of the heart is increased. In the case of the valve lesions the increase is due to the increased intraventricular pressure ; in the case of the adherent pericardium, or the myocarditis, to direct interference with the symmetrical and orderly contraction of the chambers.

(*b*) Conditions acting upon the blood-vessels : (1) General arterio-sclerosis, with or without renal disease ; (2) all states of increased arterial tension induced by the contraction of the smaller arteries under the influence of certain toxic substances ; (3) prolonged muscular exertion, which enormously increases the blood-pressure in the arteries ; (4) narrowing of the aorta, as in congenital stenosis.

Hypertrophy of the right ventricle is met with under the following conditions :

(1) Lesions of the mitral valve, either incompetence or stenosis, which act by increasing the resistance in the pulmonary vessels ; (2) pulmonary lesions with obliteration of any considerable number of blood-vessels within the lungs, such as occurs in emphysema or cirrhosis ; (3) valvular lesions on the right side occasionally, and not infrequently in the fœtus ; (4) chronic valvular disease of the left heart and pericardial adhesions.

In the auricles simple hypertrophy is never seen ; it is always dilatation with hypertrophy. In the left auricle the condition develops in lesions at the mitral orifice, particularly stenosis. The right auricle hypertrophies when there is greatly increased blood-pressure in the lesser circulation, whether due to mitral stenosis or to pulmonary lesions. Narrowing of the tricuspid orifice is a less frequent cause.

Hypertrophy or dilatation of the cardiac chambers may cause pressure, sometimes injurious, on surrounding structures.

Great enlargements of the left ventricle, as seen in the bovine heart of valvular disease, may occasion compression of the lower portion of the left lung when a deviation of the mediastinum towards the right is prevented. As a rule, such enlargement compresses the lower part of the left lung comparatively little. Enlargement of the right ventricle frequently causes a depression and forward displacement of the left lobe of the liver and the appearance of a pulsating mass in the epigastrium.

Dilatation of the auricles is more likely to produce serious compression of surrounding structures than is that of the ventricles because of the greater fixation of the heart at its upper portion where the auricles are placed. Enlargement of the left auricle has in some cases produced compression of the left bronchus with consequent

collapse of the lung. Enlargement of the right auricle seems to be the basis of the frequently occurring right-sided hydrothorax of valvular heart disease. Compression of the azygos vein and perhaps of the veins and lymphatics at the root of the right lung by the enlarged auricle accounts for the occurrence of one-sided hydrothorax (Stengel).

Rupture of the heart is usually secondary to fatty degeneration of the cardiac muscles. It may follow a complete embolic obstruction of one of the branches of the coronary arteries. Arterio-sclerosis with slow obliteration of one or both of these arteries may result in such atrophy of the myocardium as to favor rupture, and this atrophy is hastened by the fact that there is no direct anastomosis between the branches of these vessels (page 703). With any of these predisposing conditions present, rupture may follow unusual exertion, or a heavy fall, or direct violence to the precordium, or may occur spontaneously. The right side of the heart is the more frequently involved, the right auricle especially; but the cavities implicated, in order of frequency, are the right auricle, left ventricle, left auricle, right ventricle. This order probably results from the facts that (*a*) the right auricle is the weakest part of the heart; (*b*) the left ventricle, though normally the strongest part, stands second because it is specially liable to the myocardial degenerations that result from coronary arterio-sclerosis; (*c*) the left auricle and the right ventricle, though weaker than the left ventricle, are less frequently affected because they are not so liable to such degeneration.

Wound of the heart is not necessarily fatal. A stab wound may be followed by little or no hemorrhage owing to the anatomical arrangement of the muscular fibres, some of which, whatever the direction of the wound, escape division. The thicker the cardiac wall at the site of the wound the more numerous the fibres and the more effective their action in preventing hemorrhage; hence wounds of the auricles are more certainly and more rapidly fatal than wounds of the ventricles, and wounds of the right ventricle are graver than those of the left. Pain and syncopal attacks are almost always present. Hemorrhage into the pericardium will be attended by great precordial oppression, there will be increase of the area of cardiac dulness, and indistinctness or feebleness of all the heart sounds.

The anterior surface of the heart is most frequently wounded. The overlapping of the pleura (page 1860) leads to its usual involvement in wounds of the heart or pericardium, except those that reach the latter through those areas of the sternum with which they are in direct relation. Accordingly, in most heart wounds a pleural cavity —commonly the left—is found to contain blood. As the anterior margin of the lung is also apt to be involved, except when the wound is within the bounds of the area of cardiac dulness, the blood in both the pleural and pericardial cavities may be frothy.

The right auricle and ventricle and the left coronary vessels—running in the anterior interventricular groove—are most frequently wounded; the right auricle if the wound passes through the inner end of the right third, fourth, or fifth intercostal space; the right ventricle if it passes through a corresponding space to the left of the sternum.

As 40 per cent. of the reported cases operated upon for heart-wounds have recovered, it may be well to associate the study of the normal heart with that of the best method of gaining access to it for surgical purposes.

The heart should be exposed by a flap, the lower border of which corresponds to the sixth interspace, the inner border to the left border of the sternum, and the upper border to the third or, if the wound is high up, to the second interspace. The cartilages of the corresponding ribs are divided and the flap is raised, separated if possible from the pleura, and turned outward by fracturing the ribs. The pleura is separated from the pericardium, to which it does not adhere very closely, beginning towards the middle line. The pericardium is then incised and the accumulated blood evacuated, which is often a great relief to the heart, to which the pulse quickly responds. Two fingers are now inserted below and behind the apex and the heart tilted forward and sutured. If a second wound—that of exit—is suspected, it may be found by twisting the heart gently to the right or left. The sutures should go down to the endocardium, but should not enter the cavities of the heart. The pericardium is then closed, the pleura replaced, and the flaps sutured in position.

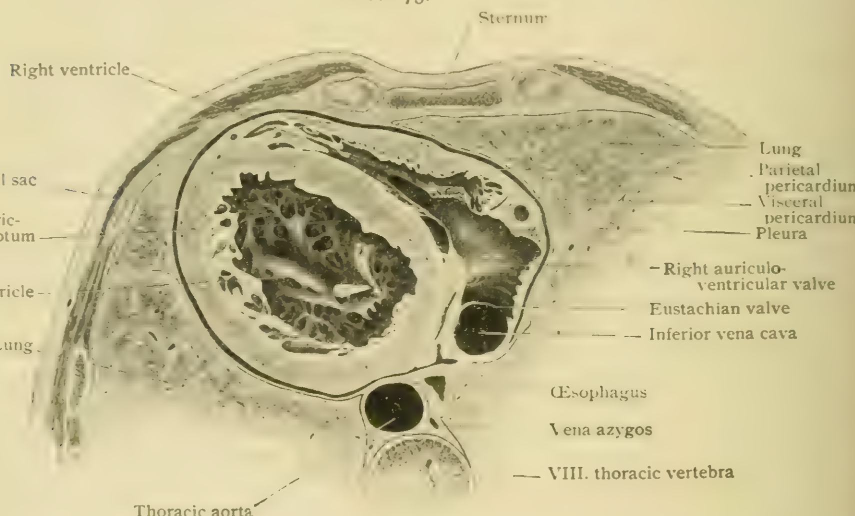
The same incision—or an extension downward of this one—will permit of sufficient exposure of the heart for cardiac massage, a method of resuscitation in desperate cases of syncope during anæsthesia which has been recently employed, but the value of which, if it has any, cannot now be estimated.

THE PERICARDIUM.

The pericardium is the serous sac which encloses the heart and the proximal portions of the great vessels. Like other serous sacs, it consists of two layers, one of which, the *visceral layer*, closely invests the heart and at its base becomes continuous with the *parietal layer*, within which it is invaginated.

The **visceral layer**, sometimes termed the *epicardium*, is an exceedingly thin membrane, and is throughout the greater part of its extent so closely adherent to the outer surface of the heart that any attempt to detach it results in injury to the superficial layers of the heart musculature. Over the right side and the anterior surface of the ventricular portion of the heart, however, a certain amount of fat, even in thin persons, occurs between the muscular tissue and the epicardium.

Fig. 675.



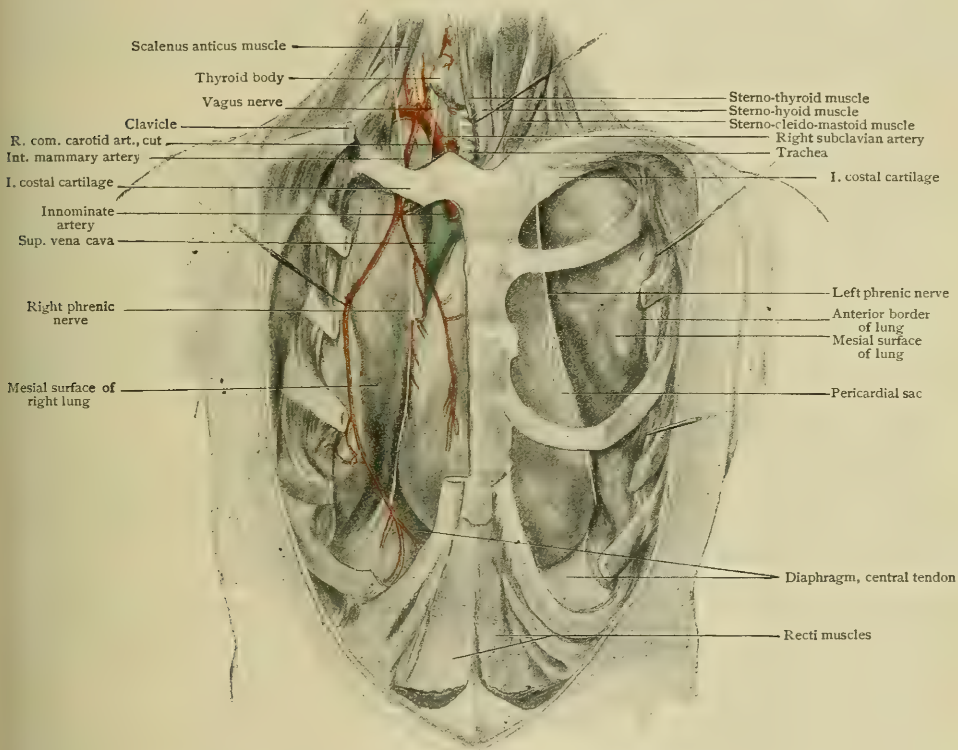
Portion of cross-section of body at level of eighth thoracic vertebra, viewed from above, showing heart enclosed by pericardium.

The **parietal layer**, much stronger than the visceral, forms a somewhat conical sac, the base of which rests upon and is attached to the diaphragm, while its apex surrounds the roots of the aortæ. Notwithstanding its greater size, no cavity exists normally between this and the visceral layer, the two being in contact throughout, except below, where, towards the periphery of the base of the parietal cone, a slight space occurs which is normally occupied by a quantity of pericardial fluid (*liquor pericardii*).

At the *sides*, and to a considerable extent on its *anterior surface*, the parietal layer of the pericardium is united to or is in close contact with the adjacent pleuræ. At the upper part of its anterior surface where it covers the aorta it is free from such contact, and over a triangular area near the base of the cone the anterior surface rests upon the posterior surface of the lower part of the sternum, to which it is united by some loose areolar tissue. *Posteriorly* it is free to a considerable extent from the pleuræ, that portion of it which covers the posterior surface of the left auricle resting upon the œsophagus and the thoracic aorta. The *base* of the cone is firmly united to the upper surface of the diaphragm throughout its entire extent, the area of attachment corresponding to the anterior and a portion of the left lobe of the central tendon.

Above, as has been stated, the parietal layer extends upward some distance upon the proximal portions of the systemic and pulmonary aortæ before passing over into the visceral layer, but the amount to which the two vessels are invested differs considerably. If the parietal layer be cut away along the line at which it becomes continuous with the visceral layer, two distinct lines will be found indicating its attachments. One of these surrounds the two aortæ (Fig. 654), which are united by connective tissue, and extends upward upon the systemic aorta to a point a little below the origin of the innominate artery, a level which corresponds very nearly with the upper border of the second costal cartilage; upon the pulmonary aorta (artery) the line does not rise quite so high, reaching to a point a little below where the vessel divides into the right and left pulmonary arteries. The other line of attachment is much more extensive and complicated (Fig. 655). Starting from its attachment to the left

FIG. 676.



Anterior thoracic wall has been partly removed, leaving left half of sternum and some ribs in place; lungs have been drawn aside to expose pericardial sac.

pulmonary veins, upon which it ascends for a short distance, it passes directly across the posterior surface of the left auricle to the base of the right pulmonary veins, and is thence continued downward to surround the vena cava inferior close to its entrance into the right auricle. Thence it passes upward to regain the right pulmonary veins, and is then continued around the vena cava superior, upon which it rises to a height of about 3 cm. It then passes towards the left over the posterior surface of the auricles to reach the starting-point at the left pulmonary veins.

The existence of these two separate lines of attachment is due to a difference in the arrangement of the visceral and parietal layers in the interval between the aortæ and the anterior surface of the auricles. The parietal layer passes directly across from the aortæ to the auricles, while the visceral layer forms an investment for the vessels, extending downward to their origin from the ventricles, and is thence

reflected upward over the anterior surface of the auricles until it again meets the parietal layer. There is thus produced, between the aorta in front and the auricles behind, a cavity or cleft, known as the *transverse sinus of the pericardium* (Fig. 654), which is continuous at either extremity with the general pericardial cavity, and is roofed in by the parietal layer, while its walls and floor are formed by the visceral layer.

In the roof of the sinus transversus a slight fold is to be found towards the left, which passes backward to the line of attachment of the roof to the left auricle and thence obliquely downward in the visceral layer covering the posterior surface of the auricle towards the coronary sinus. This duplicature, known as the *vestigial fold* of the pericardium (**ligamentum v. cavae sinistrae**), contains in its upper part a fibrous cord and in its lower part the *oblique vein* of the left auricle; these two structures, the vein and fibrous cord, together with the coronary sinus, representing the remains of an original left superior vena cava.

It may be noted that the line of attachment of the parietal layer between the left pulmonary veins and the inferior vena cava extends high up on the posterior surface of the auricles, and there is thus formed in this region a pouch-like diverticulum of the pericardium whose mouth looks downward. This is what has been termed the *oblique sinus* of the pericardium. Its parietal wall rests upon the œsophagus posteriorly, and in case of extensive effusion into the pericardial cavity, compression of the œsophagus sufficient to interfere with the act of swallowing may result.

The Ligaments of the Pericardium.—The parietal layer of the pericardium is united to the surrounding structures by areolar tissue which may condense to definite bands termed pericardial ligaments. Thus the tissue between the pericardium and the sternum may condense to form a *superior* and an *inferior pericardio-sternal ligament*, the former passing to the posterior surface of the manubrium sterni and the latter to the lower part of the gladiolus. Similarly, bundles of fibres are attached to the apex of the pericardial cone and to the great vessels of the heart, taking their origin from the prevertebral layer of the cervical fascia which is prolonged downward into the thorax; these are the *pericardio-vertebral ligaments*. And, finally, a band has been described as extending from the posterior surface of the pericardium to the upper surface of the diaphragm on either side of the vena cava inferior; these form what are termed the *pericardio-phrenic ligaments*.

The Vessels.—The *arteries* which supply the posterior surface of the parietal layer of the pericardium arise from the thoracic aorta, and those of the anterior surface are given off by the internal mammary artery. The *veins* of the parietal layer pursue courses parallel with those of the arteries, and open into the vena azygos behind and the superior phrenic or superior vena cava anteriorly.

The *lymphatics* pass to the nodes lying in the bifurcation of the trachea. The vascular supply of the visceral layer is the same as that of the muscular tissue of the heart.

The **nerves** distributed to the pericardium include fibres from the phrenic nerve, especially the left one, and also probably from the cardiac plexus.

PRACTICAL CONSIDERATIONS: THE PERICARDIUM.

The visceral layer of the pericardium is closely attached to and practically inseparable from the heart muscle. It is continuous with the parietal layer at the base of the heart where the two layers ensheathe the great vessels, covering in especially the first inch and a half of the aorta and pulmonary artery and leaving, between those vessels in front and the auricles behind, an open space—the transverse sinus—which may be the seat of an effusion walled off by adhesions from the general pericardial cavity. The least resistant important structure in immediate relation to this sinus is the superior vena cava,—also intrapericardial at its lowermost portion,—and such effusion might therefore cause fulness of the veins of the neck or even cyanosis without the evidence of a general pericardial dropsy large enough to give the usual concomitant physical signs (*vide infra*). In artificial distention of the pericardium the sac tends to assume the shape of two irregular spheres, the upper or smaller one containing the great vessels just mentioned, the lower embracing the heart, the ascending cava, and the pulmonary veins. At the apex of the heart, where the pericardium is reflected from the diaphragm, unimportant sinuses, analogous to the costo-phrenic sinus of the pleura, may exist.

The parietal layer of the pericardium is in relation with an external fibrous layer which extends beyond the serous investment of the roots of the great vessels, blends with their outer coats, and is directly continuous with the deep cervical fascia, thus connecting the pericardium with two respiratory agents, the diaphragm below and the cervical muscles (omo-hyoid) above. When these act conjointly, as in a full inspiration, they render the pericardium tense and resisting, and minimize the pressure upon the heart by the inflated lungs (page 551).

Pericarditis—probably more often overlooked than any other serious disease (Osler)—may arise from wound from without, as in ordinary penetrating wounds of the chest, or from within, as from the passage of a foreign body from the œsophagus into the pericardium (page 1614); or it may follow extension of disease from contiguous organs, as in pleuro-pneumonia. The anatomical relations of the pericardium explain these occurrences. The more usual causes, as rheumatism, septicæmia, gout, and nephritis, have no anatomical bearing.

Pericarditis is attended by certain symptoms—well detailed by Sibson—which should be studied in connection with the anatomy of the heart and pericardium.

1. *Pain*—(*a*) spontaneous and directly over the heart, the pleuræ often being involved, both these serous membranes—like the peritoneum—becoming painful when inflamed, although normally insensitive ; (*b*) elicited by pressure (tenderness), the skin over the precordium sometimes participating on account of the connection between the upper intercostal nerves and the ganglia and nerves of the cardiac plexus ; (*c*) over the epigastric region and increased by pressure, because, although normally the pericardium below is in direct relation with the thoracic parietes over only a small area behind the xiphoid cartilage, distention of the pericardial sac, as in effusion from pericarditis, carries it downward so that it may be well below the tip of the xiphoid ; (*d*) between the scapulæ or deep in the chest, increased by swallowing or by eructations, and worse when the patient is supine, due to the relation between the œsophagus and pericardium just below the aortic arch ; (*e*) in the side, usually pleuritic (from extension), and more common on the left side on account of the greater extent to which the inflamed pericardium occupies the left side of the chest than the right side, to the marked backward displacement of the lower lobe of the left lung by the distended pericardial sac, and possibly (Sibson) to the pressure of the latter on the left bronchus increasing in the left lung the tendency to intercurrent pneumonia. 2. *Feeble or irregular heart action*, due to (*a*) direct extension of the inflammation from the visceral layer of the pericardium to the heart muscle (myocarditis); (*b*) implication of the cardiac nerves ; (*c*) pressure by the pericardial effusion on the venæ cavæ and pulmonary veins, impeding the blood-supply to both auricles ; direct pressure upon the auricles interfering with the ventricular supply ; and pressure upon the whole organ both directly from the effusion and indirectly from the compressed and displaced lungs and the other contiguous structures, embarrassing its action, especially in diastole. 3. *Dyspnœa*, due to the pulmonary congestion produced by the previous causes ; sometimes the result of a pleurisy or pleuro-pneumonia by extension ; or perhaps, as Hilton has suggested, partly from fixation or irregular action of the diaphragm through irritation of the pericardiac filament of the phrenic (**ramus pericardiacus**), usually given off on the right side. 4. *Dysphagia* (page 1614) from compression of the œsophagus between the pericardium and the vertebral column, usually relieved when the patient is put in an approximately vertical position. 5. *Aphonia*, from involvement of the left recurrent laryngeal nerve by contiguity, or of both nerves through their cardiac branches. 6. *Fulness of the cervical veins and flushing or cyanosis of the face*, due to pressure upon the thin walls of the right auricle and of the superior vena cava. Compression of the left auricle is better resisted on account of the greater thickness of its walls ; when it occurs, it tends to produce pulmonary congestion or apoplexy.

The *physical signs* of pericarditis are, of course, influenced by the attachment, surroundings, and physical qualities of the pericardium.

1. As it is in two layers normally movable upon each other, the roughening caused by inflammation produces a *friction-sound* which, when typical, is (*a*) heard best over the middle and the lower half of the sternum, and over the adjoining left costal cartilages or their interspaces, because there a greater extent of the pericardium is

closer to the ear, with fewer intervening structures than elsewhere; (*b*) preceded or accompanied by pain (*vide supra*); (*c*) usually increased by pressure with the stethoscope, which brings the two roughened pericardial layers into closer apposition; (*d*) accompanied by an extension of the area of cardiac dulness (*vide infra*); (*e*) is double,—that is, corresponding, although not altogether synchronously, to both systole and diastole; and (*f*) may disappear when effusion occurs,—separating the two layers,—or may persist over a small area near either the diaphragmatic attachment or the pericardial reflection at the base.

2. As the pericardium is markedly elastic, when effusion takes place the parietal layer may stretch so that the pericardial cavity may hold ten or twelve ounces instead of a few grammes, or in chronic cases may contain several pints. As its cavity is in the shape of that of a hollow cone or pear, the apex corresponding to the fixed portion of the heart—held in place by the great vessels—and the base—enlarged to permit the considerable degree of motion of the heart's apex—to the upper surface of the diaphragm, pericardial effusions also take this general shape, and the area of *percussion-dulness* will be found to have its base—about on a level with the fifth or sixth interspace—inferior, and its apex—about on a level with the second interspace—directed upward towards the first segment of the sternum. It is more marked to the left of the sternum on account of the larger area of heart and pericardium on that side, but may be found to the right of the sternum, especially about the fifth intercostal space (Rotch), because on the right side (owing to the presence of the right lobe of the liver) the lower border of the distended sac is somewhat higher than on the left.

3. As such enlargement must affect the contiguous organs and the overlying parietes, there will be found in full distention: (*a*) prominence of the intercostal spaces, especially on the left side, or of the left antero-lateral thoracic walls, of the epigastrium (from depression of the diaphragm and left lobe of the liver), of the lower two-thirds of the sternum, or, in children with yielding thoracic walls, of the whole precordia; (*b*) compression of the left lung, sometimes causing a tympanitic percussion-note in the left axillary region; (*c*) compression, between the relatively unyielding sternum and the dorsal spine, of the trachea and left bronchus (irritative cough), the œsophagus (dysphagia), and the aorta (affecting the systemic blood-supply); (*d*) a backward curve of the dorsal spine has been described (Sibson) as resulting from the necessity of limiting pressure on these important structures; (*e*) compression or irritation of the recurrent laryngeal nerve (aphonia) and the superior vena cava (venous engorgement of neck and face) have been noted (*vide supra*).

4. The upward displacement of the heart itself, due to (*a*) its attachments to the great vessels fixing its upper portion; and (*b*) the effect of gravity upon the effusion which distends the lower part of the sac, separates to an extent the chest-walls and the inferior portion of the right ventricle, and occupying the space between the lower surface of the heart and the tendinous centre of the diaphragm, forces the former organ into the upper part of the pericardial sac, causes a corresponding *alteration in the cardiac impulse*, which is diminished or obliterated, and a *change in the position of the apex beat*, which may be found at the third or fourth interspace instead of at the fifth; as the upper portion of the chest is the narrower, and as the left lung has been pushed aside by the distended sac, the apex beat may also be found much nearer a vertical line drawn through the nipple than is normally the case.

Either *paracentesis pericardii* or incision of the pericardium for the purpose of tapping or of draining the sac in cases of purulent effusion may be done in the fifth or sixth intercostal space on the left side about one inch from the sternum. The internal mammary artery descends vertically about a half inch from the margin of the sternum. The pleura is often pushed by the distended sac beyond the point mentioned. If not, the trocar would penetrate its two layers if inserted one inch from the sternal border. In the sixth interspace there is somewhat less danger of wounding the heart. Incision close to the edge of the sternum will usually avoid both of these risks. Incision or puncture in the fifth space on the right side has been advised as minimizing the danger to the heart. Deguy (quoted by Treves) advises subperiosteal resection of the xiphoid cartilage by a median incision, downward detachment of the diaphragmatic muscle-fibres, and dissection through the loose cellular tissue to the pericardium, which is seized, drawn down and forward, and incised.

THE GENERAL PLAN OF THE CIRCULATION.

The blood which enters the right auricle of the heart by way of the superior and inferior venæ cavæ and the coronary sinus is blood which has come from the tissues, to which it has delivered the oxygen and nutritive material and from which it has received carbon dioxide and other waste products. From the right auricle this blood passes through the right auriculo-ventricular orifice into the right ventricle, and on the contraction of this, which follows immediately upon the contraction of the auricle, it is forced into the pulmonary aorta (pulmonary artery), the tricuspid valve preventing regurgitation into the auricle. Upon the completion of the contraction of the ventricle, the blood which has been forced into the pulmonary aorta and is distending its walls forces together the pulmonary semilunar valves and, consequently, by the contraction of the walls of the vessel and by subsequent contractions of the ventricle, sending new blood into the vessel, is forced onward towards the lungs. In the substance of these organs the pulmonary vessels divide repeatedly, and finally form a dense net-work of capillaries, through the walls of which an interchange of gases between the blood and the air contained in the cavities of the lungs takes place. From the pulmonary capillaries the pulmonary veins arise and carry the purified blood back to the heart, emptying it into the left auricle.

In this course the blood has passed from the heart through a set of capillaries back to the heart, and in one sense it has completed a circuit, which is termed the *minor* or *pulmonary circulation*. In reality, however, it is not a perfect circuit, since, while beginning in the right side of the heart, it terminates in the left side. In order to reach again the right side, it is necessary for it to pass through the *major* or *systemic circulation*, the general course of which is as follows.

From the left auricle the blood passes through the left auriculo-ventricular orifice into the left ventricle, and by the contraction of this is forced into the systemic aorta, or, as it is more frequently termed, the aorta, the bicuspid valve preventing its passage back into the auricle. The aorta curves backward and to the left and passes down the body lying upon the left side of the vertebral column, and in its course gives off branches which distribute the blood to all parts of the body. In the various organs these branches break up into a net-work of capillaries, from which veins lead the blood into either the superior or the inferior vena cava or into the coronary sinus, from which it passes to the right auricle.

In the systemic, as in the pulmonary circulation, the blood passes from the heart, through one set of capillaries, and back to the heart. In the case of the blood which traverses the vessels passing to the stomach, the intestines (with the exception of the lower portion of the rectum), the pancreas, and the spleen, however, a modification of this arrangement occurs, in that before returning to the heart the blood is required to pass through *two* sets of capillaries. The first set is in the substance of the organs named, and after passing through this the blood is collected into a vein, the vena porta, which conveys it to the liver. Here the portal vein breaks up into the second set of capillaries, through which the blood passes to the hepatic veins, which open into the vena cava inferior, and thus return the blood to the right auricle. This portion of the major circuit forms what is termed the *portal circulation*.

THE ARTERIES.

The arteries are those vessels which conduct the blood away from the heart. Since the blood is forced into the arteries under considerable pressure by the contraction of the ventricles, it is necessary that the walls of these vessels should be sufficiently strong to withstand pressure, and at the same time elastic so as to yield to each successive injection of blood from the heart and to return to the normal calibre when the wave has passed. As the blood courses from the main vessels to the capillaries, it passes through channels of progressively decreasing calibre, and is, therefore, constantly encountering increased resistance, whereby the arterial pressure is diminished, until finally, when the capillaries are reached, the pressure is practically nothing. As the pressure is reduced, the thickness of the arterial walls diminishes,

so that, as a rule, it may be stated that the thickness of the wall of an artery is directly proportional to the calibre of the vessel. Exceptions to the rule exist, however, and the thickness of the wall is not necessarily the same in vessels of identical calibre.

Another general rule, to which there are also exceptions, is to the effect that the calibre of an artery is proportional to the extent of territory which it supplies. At each point where a branch is given off from an artery a diminution of the calibre occurs, but throughout the interval between successive branches the size of the vessel usually remains unchanged. Where, however, a marked alteration in the direction of an artery occurs, its diameter undergoes a slight diminution, but is re-established, or, indeed, increased for a short distance, so soon as the change of direction is accomplished. These constrictions, which are especially noticeable in large arteries, such as the aortic arch or the subclavian, are termed *arterial isthmuses*, and the enlargements which succeed are known as *arterial spindles*.

The area of the transverse section of a left subclavian artery before any branches were given off was found to be 27.6 sq. mm., that of a section of the isthmus was 15.6 sq. mm., while that of a section taken about 2 cm. beyond the isthmus was 20 sq. mm. In the case of an aorta in which the spindle was well marked, the area of a transverse section of the isthmus was found to be 46 sq. mm., that of a section through the spindle was 65 sq. mm., and that of a section of the thoracic aorta a little below the spindle was again 46 sq. mm. (Stahel).

THE GENERAL PLAN OF THE ARTERIAL SYSTEM.

An idea of the general plan of the arterial system may be most readily obtained by reference to the arrangement occurring in the fishes (Fig. 677), in which respiration is performed by gills borne upon a series of branchial bars which form the lateral walls of the pharynx. In these forms the heart consists of but two chambers, an *atrium* which receives the great veins and a *ventricle* from which a single aortic trunk, the *truncus arteriosus*, arises. The heart contains only venous blood, and its function is to drive the blood through the gills, where it becomes oxygenated, and whence it passes to the various organs of the body. The heart is situated far forward, beneath the posterior portion of the pharynx, and the aorta passes forward from it along the floor of the pharynx, sometimes dividing early into two parallel stems, the *ventral aortæ*. From these, and from the aorta before its division, branches pass off to each of the gill-arches and, breaking up into capillaries, traverse the gill-filaments borne by the arches. After being oxygenated in the gill-filaments, the blood from each gill is collected again into a stem which joins with those coming from the other gills of the same side of the body to form a longitudinal trunk situated on the roof of the pharynx, and this trunk, passing backward, unites with its fellow of the opposite side to form a *dorsal aorta*, which is continued throughout the entire length of the body immediately beneath the vertebral column.

From the forward part of each of the dorsal longitudinal stems branches are continued forward into the head region, and throughout the entire trunk region the dorsal aorta gives off laterally paired branches corresponding to each of the segments of the trunk, and from its ventral surface one or two series of visceral branches which are also arranged segmentally.

At one stage in the development of the human embryo the arrangement of the arterial system is essentially the same as that which has just been described, except that, since there are no longer any gill-filaments, the capillaries of the branchial vessels are lacking. By a series of important changes, later to be described (page 846), this arrangement is converted into that found in the adult, the relation between the human arrangement and that occurring in the fishes being shown by a comparison of the preceding diagram with Fig. 678. It will be seen that the fourth branchial arch of the left side is represented by the arch of the aorta, the anterior portion of the dorsal aorta becomes what is termed the internal carotid artery, the forward prolongation of the ventral aorta becomes the external carotid artery, and the connecting link between these two vessels represents the third branchial vessel. And, finally, the last pair of branchial vessels is represented by the pulmonary arteries.

While the arteries have their primary embryonic arrangement, the heart lies far forward beneath the posterior portion of the pharynx. Later, however, it undergoes

a regression whereby it becomes situated in the thorax, and in this migration it carries backward (downward) with it the pulmonary arteries and the arch of the aorta and produces an elongation of the carotids. As a result of the regression of the aortic arch, the lateral branches which arose from the anterior portions of the dorsal aorta and were distributed to the cervical segments of the body become sepa-

FIG. 677.

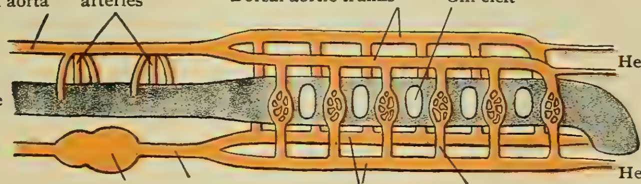


Diagram showing fundamental arrangement of arteries in fish, supposed to be viewed from the side and above; shaded tube represents digestive canal with its gill-clefts in front surrounded by series of six aortic bows and behind by segmental arteries.

rated from their origins as far down as the branch to the seventh cervical segment, which becomes the adult subclavian artery, but having developed anastomoses with one another, so that a longitudinal stem, running parallel with the internal carotid and attached below to the subclavian, is formed, they appear in the adult as lateral branches of that stem which is termed the vertebral artery. Primarily there are no longitudinal arteries in the body, with the exception of the carotids and the dorsal aorta; but just as the vertebral artery is formed in the neck by the anastomosis of upwardly and downwardly directed branches from lateral vessels, so, too, in other regions, such as the thoracic and abdominal walls, other longitudinal stems are secondarily developed.

The dorsal aorta throughout its course gives off with almost segmental regularity lateral branches to the body-walls which form the intercostal and lumbar arteries, the fifth lumbar branches becoming greatly enlarged to supply the lower limb, and being termed the iliac arteries. Below the origin of these the aorta is represented only by a comparatively slender vessel, the middle sacral artery, which is continued to the tip of the coccyx, giving off lateral branches with a more or less distinct segmental arrangement. The visceral branches which arise from the aorta do not retain their original segmental arrangement as perfectly as do the branches to the body-walls, but fuse to a very considerable extent, especially in the abdomen, to form a small number of vessels which ramify to the various portions of the digestive tract and to the genito-urinary abdominal organs.

FIG. 678.

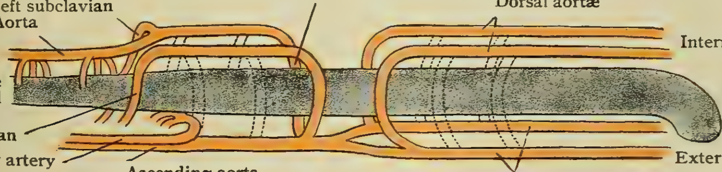


Diagram showing derivation of arteries in man by modifications in preceding plan; left fourth aortic bow becomes aortic arch.

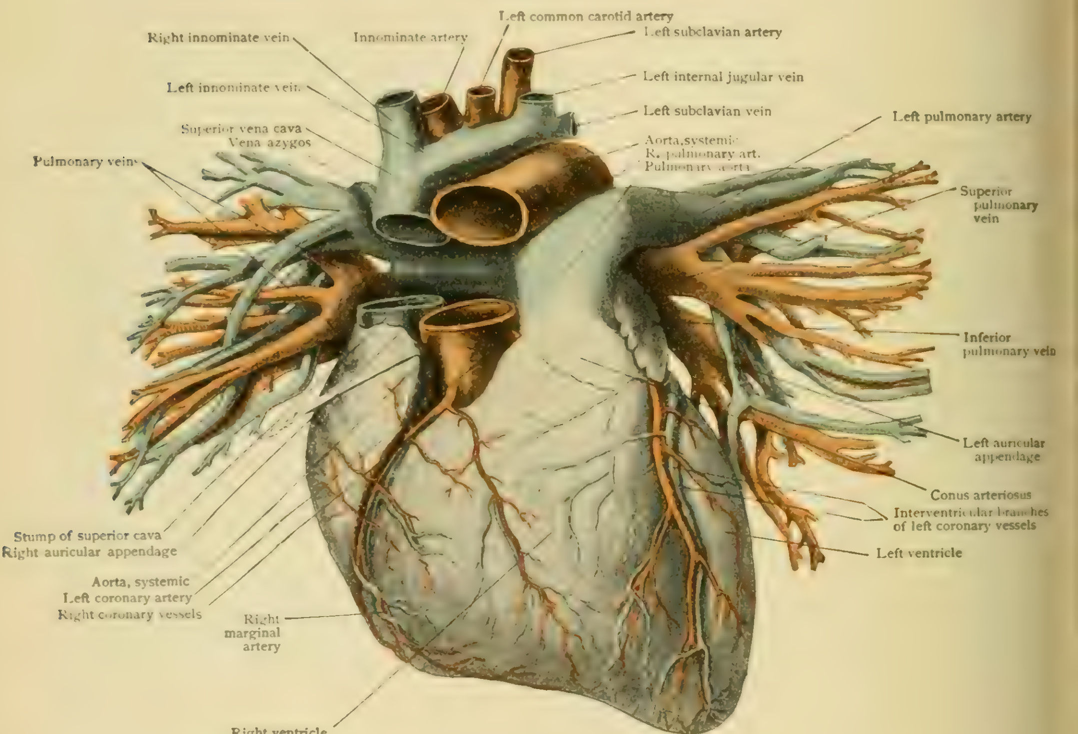
It will be seen, therefore, that the arterial system consists of two fundamental portions, a *branchial* and a *dorsal aortic* portion. A classification of the vessels of the adult according to such a plan would, however, result in considerable confusion, since, owing to the secondary modifications which have occurred, it would necessitate the separation into different groups of arteries which are closely related, and,

conversely, would associate quite distinct vessels. It will be more convenient, therefore, to employ a topographic classification, according to which two main subdivisions of the system—that of the *pulmonary aorta* and that of the *systemic aorta*—may be recognized, the systemic subdivision being again divided into the *aortic arch*, the *thoracic*, and the *abdominal portions*.

THE PULMONARY AORTA.

The pulmonary aorta, most frequently termed the **pulmonary artery** (**a. pulmonalis**) takes its origin from the summit of the conus arteriosus of the right ventricle. It is from 4.5–5 cm. (about 2 in.) in length, and is directed upward, backward, and slightly towards the left, and beneath the arch of the aorta it divides into the right and left pulmonary arteries (Fig. 679).

FIG. 679.



Injected heart and great vessels, viewed from before; part of superior vena cava and aorta have been removed to show right pulmonary artery.

Relations.—Throughout the greater portion of its length the pulmonary aorta is invested by that part of the visceral layer of the pericardium which surrounds it and the basal portion of the systemic aorta. At its origin it is partly overlapped in front by the tip of the right auricular appendix, and posteriorly it is in relation with the base of the systemic aorta and the proximal portion of the right coronary artery. More distally it lies to the left of the systemic aorta and rests upon the anterior surface of the left auricle.

Branches.—The **right pulmonary artery** (**ramus dexter**) has an almost transverse course from its origin towards the base of the right lung. It passes outward above the right auricle, behind the ascending portion of the systemic aorta and the superior vena cava and in front of the right bronchus. At the root of the lung it divides into three branches which are distributed to the three lobes of the lung.

The **left pulmonary artery** (**ramus sinister**) is somewhat shorter than the right, and passes outward in front of the descending portion of the aortic arch and the left bronchus to the root

of the left lung, where it divides into two branches to be distributed to the lobes of the lung. From the upper border of the artery a short cylindrical cord passes to the under surface of the transverse portion of the aortic arch, a little beyond the point at which the left subclavian artery arises from its upper convex surface. This cord is the remains of a communication between the pulmonary and systemic aortæ which exists in fœtal life, when the lungs are not functional, and is termed the **ductus arteriosus.** It represents the outer portion of the vessel of the sixth branchial arch of the left side, and its lumen usually becomes occluded during the first few months after birth, so that, as a rule, the cord is solid in the adult.

Variations.—The majority of the variations that have been observed in the pulmonary aorta are associated with serious malformations of the heart which usually result in early death, and are consequently to be classed as pathological rather than as merely anomalous conditions. A precocious division of the main stem of the pulmonary aorta occasionally occurs, absence of the right pulmonary artery has been observed, and an accessory coronary artery has been noted arising from the pulmonary aorta.

Failure of the ductus arteriosus to undergo complete occlusion is a not infrequent occurrence, and is often associated with a persistence of the foramen ovale. The ductus has also been observed to arise directly from the right ventricle.

THE SYSTEMIC AORTA.

The systemic aorta, or, as it is more commonly and more simply termed, the **aorta,** is the main arterial stem for the supply of the tissues of the body. It arises from the base of the left ventricle and curves in an arch-like manner to the left side of the vertebral column, along which it runs to the level of the fourth lumbar vertebra. There it gives off a pair of large common iliac arteries, and is continued onward, much reduced in size, along the ventral surface of the sacrum and coccyx, being termed in this portion of its course the middle sacral artery.

It may be regarded, for the purpose of description, as being composed of three portions : (1) the *aortic arch*, which extends from the heart to the left side of the body of the fourth thoracic vertebra ; (2) the *thoracic aorta*, extending from the lower end of the aortic arch to the diaphragm ; and (3) the *abdominal aorta*, extending from the diaphragm to the fourth lumbar vertebra. The middle sacral artery may most conveniently be treated as a branch of the abdominal aorta.

THE AORTIC ARCH.

The aortic arch arises from the base of the left ventricle (Figs. 679, 690), and in the first or *ascending portion* (**aorta ascendens**) of its course is directed upward and somewhat forward and to the right. It then curves to the left and backward as the *transverse portion* (**arcus aortae**), and finally bends downward as the *descending portion* along the left side of the body of the fourth thoracic vertebra, to become continuous with the thoracic aorta.

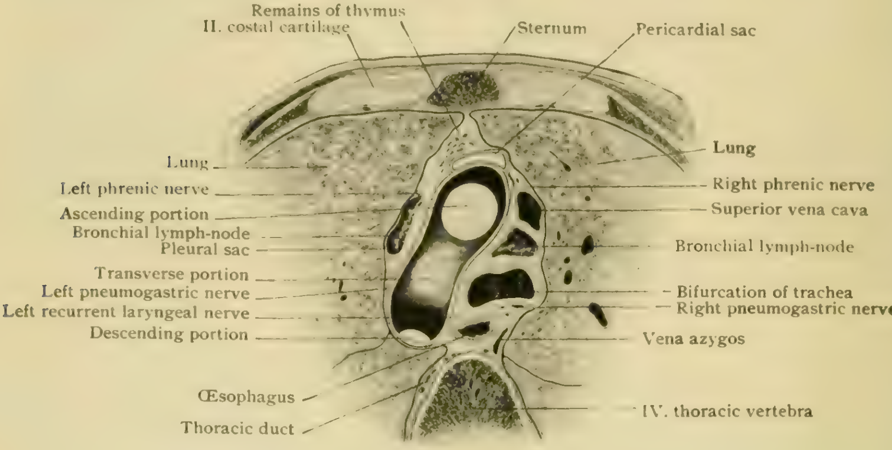
At its origin the aortic arch presents three rounded swellings, one anterior and the other two postero-lateral, marking the position of the sinuses of Valsalva (**sinus aortae**). The diameter of the ascending portion is about 2.7 cm. and that of the descending portion about 2 cm., the diminution appearing rather suddenly below the origin of the left subclavian artery and forming what has been termed the *aortic isthmus.* Where the ascending portion passes over into the transverse an enlargement of the diameter occurs which is especially well marked in older individuals, and is presumably due to the impact of the blood forced out of the ventricle by its contractions.

At about the junction of its transverse and descending portions the arch has attached to its under surface the fibrous cord which represents the fœtal ductus arteriosus.

Relations.—The **ascending portion** of the arch is enclosed throughout almost its entire length (about 5 cm., or 2 in.) in the sheath, formed by the visceral layer of the pericardium, which it shares with the pulmonary aorta. At its origin it lies behind and somewhat to the left of that vessel, but higher up crosses it obliquely, so that it comes to lie upon its right side ; to the right and left it is in relation with the corresponding auricles, and anteriorly its upper portion is separated from contact with the sternum by a more or less abundant fatty tissue in which are the remains of the thymus gland. Posteriorly it is in relation with the anterior surface of the auricles.

The **transverse portion** is crossed on its anterior surface by the left phrenic, cardiac, and pneumogastric nerves, arranged in that order from right to left, the pneumogastric crossing it on a level with the origin of the left subclavian artery.

FIG. 680.



Part of cross-section of body at level of fourth thoracic vertebra, viewed from above; upper part of aortic arch has been removed.

More posteriorly the anterior surface is in contact with the left pleura. Behind it is in relation from right to left with the superior vena cava, the trachea, the œsophagus, and the body of the fourth thoracic vertebra, and below it are the right pulmonary artery, the left recurrent laryngeal nerve, and the left bronchus, the arch crossing this last structure obliquely from above downward and outward.

The **descending portion** of the arch has in front of it a portion of the left pleura and the root of the left lung. Behind, it rests upon the fourth thoracic vertebra; to the right of it are the œsophagus and the thoracic duct and also the body of the fourth thoracic vertebra, and to the left are the left pleura and lung.

FIG. 681.

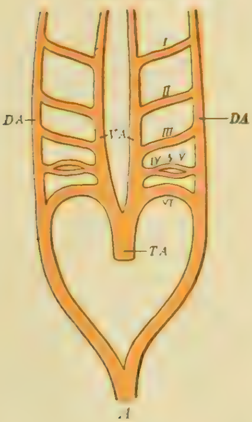


Diagram showing primary arrangement of longitudinal stems and series of six aortic bows; *TA*, truncus arteriosus; *VA*, *DA*, ventral and dorsal aortæ; *A*, unpaired dorsal aorta; *I–VI*, aortic bows, of which *V* is rudimentary.

Branches.—Just above its origin the aortic arch gives off (1) the *right* and *left coronary arteries*, and from the upper or convex surface of the transverse portion there arise in succession, from right to left, (2) the *innominate* or *brachio-cephalic*, (3) the *left common carotid*, and (4) the *left subclavian artery*.

Variations.—Owing to the complexity of the changes by which the primary arrangement of the branchial arch vessels is transformed into the adult arrangement (Figs. 681, 682), and owing also to the possibility of some of the normal changes remaining uncompleted, the variations which occur in connection with the arch of the aorta are rather numerous. They may be conveniently classed in five groups.

FIG. 682

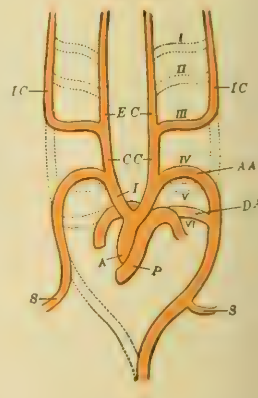
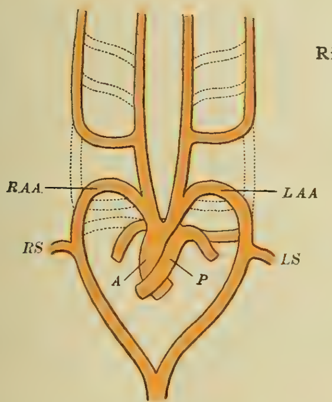


Diagram showing normal derivations in man of primary vessels by modification of preceding plan; *A*, aorta; *AA*, aortic arch; *I*, innominate artery; *CC*, common carotids; *EC*, *IC*, external and internal carotids; *S*, subclavian artery; *P*, pulmonary artery; *DA*, ductus arteriosus.

Group I.—In the normal development (Fig. 682) the distal portion of the right aortic arch degenerates as far up as the right subclavian artery, indications of it persisting as a more or less rudimentary *vas aberrans* arising from the thoracic aorta. This degeneration may not occur, both the right and left aortic arches persisting in their entirety (Fig. 683); and, since in

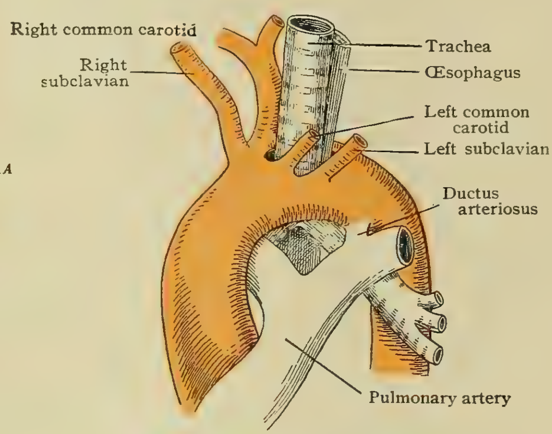
such cases the descending aorta usually retains its normal position to the left of the spinal column, a condition is produced in which the aortic arch appears to be split lengthwise into two portions, one of which, the left arch, passes in front of the trachea and œsophagus and gives origin to the left common carotid and the left subclavian arteries, while the other passes

FIG. 683.



Developmental variations of Group I, giving rise to anomaly shown in next figure. *RAA*, *LAA*, right and left aortic arches; *RS*, *LS*, subclavian arteries; *A*, aorta; *P*, pulmonary artery.

FIG. 684.



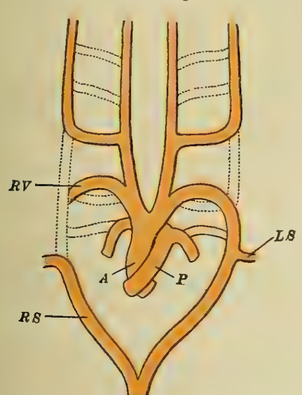
Double aortic arch through which trachea and œsophagus pass. (*Hommel*).

behind the structures named and gives origin to a right common carotid and a right subclavian (Fig. 684).

The relative diameters of the two portions of the aortic arch so formed may vary considerably, that passing in front of the trachea (the true left arch) being sometimes larger and at other times smaller than the other one. In the latter case an obliteration of the distal portion of the left arch may occur, and the left common carotid and left subclavian arteries will then appear to arise close to the innominate stem, from a common trunk, the aortic arch passing to the left behind the trachea.

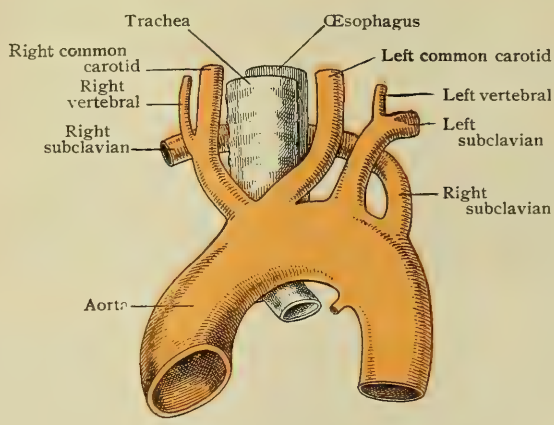
Group II.—A more frequent anomaly is the complete persistence of the distal portion of the right aortic arch (Fig. 685) associated with the disappearance of a greater or less portion of

FIG. 685.



Developmental variations of Group II, giving rise to anomaly shown in next figure. *A*, aorta; *P*, pulmonary artery; *RS*, *LS*, right and left subclavian arteries; *RV*, right vertebral artery.

FIG. 686.



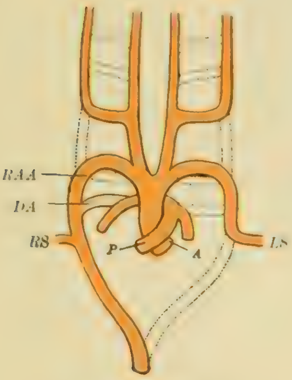
Origin of right subclavian artery from descending aorta.

its proximal part, the result being the apparent origin of the right subclavian artery from the descending aorta, whence it passes to the right behind the trachea and œsophagus. Variations of this condition, depending upon the location and extent of the disappearing portion of the right arch, may modify the relations of the right vertebral and subclavian arteries. Thus, in some

cases the vertebral may arise as in the normal arrangement from the subclavian, or it may, as it were, exchange positions with the subclavian, arising from the descending aorta, while the subclavian arises, in common with the right common carotid, from an innominate stem; or the vertebral may arise with the right common carotid from the innominate stem, the subclavian alone coming from the descending aorta (Fig. 686).

Group III.—A third group of anomalies depends upon the complete persistence of the right aortic arch, associated with the disappearance of the distal portion of the left one (Fig. 687). In such cases the result is a complete reversal of the aortic arch and its branches, unaccompanied, however, by a reversal of any of the other organs of the body, and thus differing from a true situs inversus viscerum. The arch is directed from left to right, and gives rise to an innominate stem, from which the left common carotid and left subclavian arteries arise, a right common carotid and a right subclavian, the descending aorta lying upon the right side of the vertebral column. Variations of these anomalies concern principally the relations of the ductus arteriosus or the cord which represents it. It may unite with the descending aorta, in which case it is the persistent right sixth branchial vessel, or it may be formed, as usual, from the left sixth branchial vessel, communicating distally with the left subclavian, this artery, in cases where the ductus remains patent, appearing to arise by two roots, one from the innominate stem and one from the pulmonary aorta.

Fig. 687.



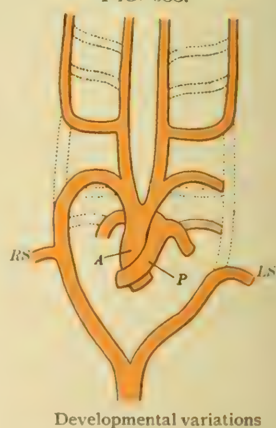
Developmental variations of Group III. *A*, aorta; *P*, pulmonary artery; *RAA*, right aortic arch; *DA*, ductus arteriosus; *RS*, *LS*, right and left subclavian arteries.

Group IV.—In the fourth group there is a complete persistence of the right aortic arch associated with a disappearance of the proximal portion of the left arch (Fig. 688), the resulting arrangement being the reverse of that seen in cases belonging to the second group. The left subclavian artery appears to arise from the descending aorta, which lies upon the right side of the vertebral column, and passes to the left behind the trachea and œsophagus. Variations in the relations of the ductus arteriosus, similar to those mentioned as occurring in the third group, may be found.

Group V.—A fifth group includes those cases in which the arch itself is normal, but in which there are variations in the vessels that arise from it. These variations may be either a diminution or an increase of the normal number of vessels or an abnormal arrangement of a normal number. The diminution and altered arrangement of the vessels depend upon a shifting of more or fewer of them, so that, for example, the left common carotid and left subclavian arteries may arise from a common left innominate stem, all the vessels may arise from a common stem, the two common carotids may have a common origin, while the two subclavians arise independently, or, what is the most frequent of these variations, the left common carotid may arise from the innominate stem and pass upward and to the left obliquely across the front of the trachea.

An increase in the number of vessels may be brought about by the independent origin from the arch of both the right common carotid and the right subclavian, the innominate being absent. In other cases, vessels which normally do not come into relation with the arch may take origin from it, this being most frequently the case with the vertebral arteries and less frequently with the internal mammaries; and, finally, an additonal branch to the thyroid gland, the art. thyroidea ima, occasionally takes origin from the arch.

Fig. 688.



Developmental variations of Group IV. *A*, aorta; *P*, pulmonary artery; *RS*, *LS*, right and left subclavian arteries.

Practical Considerations.—The Aortic Arch and Thoracic Aorta.—*Surface Relations.*—The ascending aorta begins beneath the sternum just to the right of the inner end of the third left costal cartilage. It ascends obliquely and towards the upper border of the second right costal cartilage. The second (transverse) part passes backward and to the left, crossing the mid-line about an inch from the suprasternal notch, the lower (concave) border corresponding in level with the ridge between the manubrium and the gladiolus, the upper (convex) border to the level of the third thoracic spinous process, to the middle of the manubrium, and the middle of the first costal cartilage. This border is about one inch below the suprasternal notch. The surface relations of this portion vary with the development of

the thorax. In persons with small chests the upper border may almost reach the level of the top of the manubrium, while in those with large chests it may be no higher than the junction of the first and second pieces of the sternum (*angulus Ludovici*). The transverse portion reaches the left side of the vertebral column at a level just above the fourth thoracic spine. The third (descending) portion and the thoracic aorta lie at first a little to the left of the body of the fourth thoracic vertebra and gradually incline to the mid-line, passing through the diaphragm at the level of the twelfth thoracic vertebra.

Aneurisms of the aorta are more frequent than are those of any other vessel, on account of the great strains to which the aorta is subject. They may most conveniently be considered here by following the anatomical subdivisions of the vessel, premising, however, that the symptoms thus described frequently commingle and overlap.

A. The ascending portion is more subject to aneurism than are the remaining portions, because it receives the first and most vigorous impulse of the heart's stroke, and because it is within—enclosed by—the pericardium, and its walls are not reinforced by blending with the fibrous pericardial layer, as is the case in the second and third portions. Aneurism most frequently involves the region of the anterior sinus of Valsalva, where regurgitation of blood chiefly takes place; or, if higher, the anterior wall of the aorta in the vicinity of the normal dilatation, probably due to the impact of the blood-current leaving the heart. The symptoms are: 1. *Venous congestion*, causing (*a*) *lividity of the face* from pressure on the descending cava, the left innominate, and the internal jugular veins; (*b*) *dizziness and headache* from the same cause; (*c*) *swelling and œdema of the right arm* from pressure on the subclavian vein; (*d*) *swelling and œdema of the anterior thoracic wall* from pressure on the internal mammary, azygos, or hemiazygos veins. 2. *Dyspnœa* with altered breath sounds over the right chest, from pressure on the root of the right lung. 3. *Dysphonia* or *aphonia*, with croupy or stridulous respiration, from pressure on the right recurrent laryngeal nerve; sometimes from venous congestion due to pressure on the internal jugular and innominate acting through the superior thyroid and inferior thyroid veins on the corresponding laryngeal veins. 4. *Swelling* or *tumor*, often first seen at or about the sternal end of the third right intercostal space. 5. *Displacement of the heart*, occasionally occurring when the aneurism involves especially the concave side of the vessel and pushes the heart downward and to the left. 6. *Ascites and œdema of the legs and feet* from compression of the ascending cava when the aneurism occupies the same situation. 7. *Pain* in the sternum, the ribs, or the spine from direct pressure; encircling the upper part of the chest from pressure on the intercostal nerves; running down the side of the thorax and the inner surface of the arm from pressure on fibres distributed by the intercosto-humeral nerve.

B. Aneurism of the transverse portion may cause: 1. *Dyspnœa* and *dysphonia* or *aphonia* from direct pressure on the trachea or bronchi, or from involvement of the left recurrent laryngeal nerve in its course around the arch. 2. *Dilatation of the pupil* followed by *contraction* from, first, irritation and then paralysis of the sympathetic. 3. *Inanition* from pressure on the thoracic duct. 4. *Swelling*, beginning in the mid-line, then extending to the right (only four left-sided cases out of thirty-five aneurisms, Browne, quoted by Osler), and sometimes simulating innominate or common carotid aneurism. 5. *Venous congestion* of the head, neck, left arm, etc., often more marked on the left side from the greater exposure to pressure of the left innominate vein. 6. *Weakness* or absence of radial or temporal pulse—especially on the left side—due to pressure on or involvement of the innominate, left subclavian, or left carotid artery.

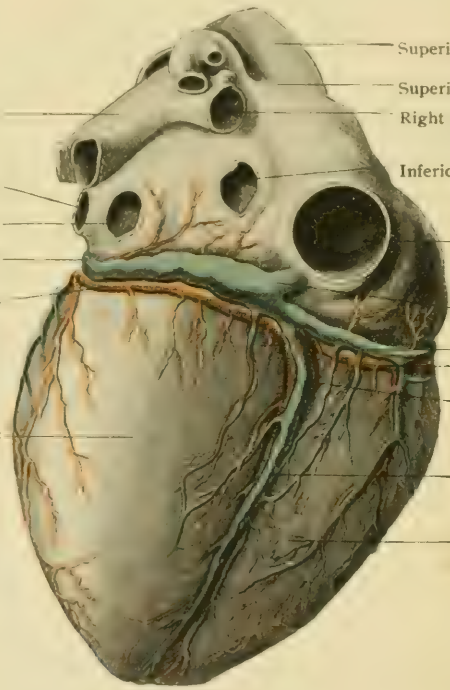
C. Aneurism of the descending portion of the arch and of the thoracic aorta may cause: 1. *Dysphagia*, which is common and apt to appear earlier on account of the more direct relation with the œsophagus. 2. *Great pain in the spine*, sometimes followed by paralysis, from erosion of the vertebræ and compression of the cord. 3. *Swelling* in the left scapular region or at the vertebral ends of the middle ribs on the left side. 4. *Bronchiectasis*, with cough and expectoration, from pressure on the left bronchus, or *asthmatic attacks* from involvement of the left pulmonary plexus.

THE CORONARY ARTERIES.

The coronary arteries, which supply the heart, are two in number, and arise from the right and left prominences at the base of the aorta which mark the corresponding sinuses of Valsalva.

The **left coronary artery** (**a. coronaria sinistra**) lies at its origin (Fig. 679) behind the base of the pulmonary aorta, and passes forward between that vessel and the left auricular appendix to reach the anterior interventricular groove, in which it divides into two branches. The larger of these (**ramus descendens anterior**) descends in the groove to the apex of the heart, giving off branches which supply the anterior surface of both ventricles, while the smaller one (**ramus circumflexus**) passes backward in the left portion of the auriculo-ventricular groove and gives off branches to the left auricle and ventricle. Branches to the left auricle also arise from the main stem of the artery, as well as twigs to the walls of the aortæ.

FIG. 689.



Postero-inferior surface of injected heart, viewed from below and behind.

The **right coronary artery** (**a. coronaria dextra**) passes outward from its origin in the right portion of the auriculo-ventricular groove, in which it lies, until it reaches the posterior interventricular groove, down which it (**ramus descendens posterior**) is continued towards the apex of the heart (Fig. 689). In its course it gives off numerous branches, which are distributed to the right auricle and ventricle and to the portion of the left ventricle which adjoins the posterior interventricular groove. Usually a large branch, the *marginal artery*, descends along the right border of the heart (Fig. 679) and gives branches to both surfaces of the right ventricle.

The peculiarities of the ultimate distribution of these arteries have been described in connection with the heart (page 703).

Variations.—The two coronary arteries may arise by a common stem; one of them may be wanting, or supernumerary vessels may occur.

THE INNOMINATE ARTERY.

The innominate artery (a. **anonyma**) (Figs. 679, 690), also known as the *brachio-cephalic*, is the first as well as the largest of the three vessels which arise from the arch of the aorta. It passes directly upward to the level of the right sterno-clavicular articulation, where it divides into the right common carotid and the right subclavian, but gives rise to no other branches.

Relations.—*Anteriorly* it is separated from the sternum and from the origins of the right sterno-hyoid and sterno-thyroid muscles by the left innominate vein and by some fatty tissue which contains the remains of the thymus gland. *Posteriorly* it is in relation with the trachea and the sympathetic cardiac nerves ; on the *right* it is in contact with the right pleura and on the *left* of it is the left common carotid artery.

Variations.—The variations of the innominate artery have already been discussed in connection with the variations of the aortic arch, since the vessel represents the proximal portion of the right arch. It shows considerable variation in length, measuring between 2.8 and 4.5 cm., although occasionally reaching a length of 5 or even 7 cm. Occasionally it is absent, the right common carotid and the right subclavian arteries arising directly from the aortic arch.

Although the innominate artery does not, as a rule, give origin to any branches except the two terminal ones, yet in about 10 per cent. of cases there arises from it a vessel which is termed the **arteria thyroidea ima.** This takes its origin usually from near the base of the innominate, upon its medial surface, and passes directly upward upon the anterior surface of the trachea to terminate in branches which are distributed to the isthmus and the lower portions of the lobes of the thyroid body. The presence of this thyroidea ima is frequently associated with a more or less extensive reduction of the size of one or other of the inferior thyroid arteries, and, indeed, these arteries may be entirely supplanted by it. It is somewhat variable in its origin, for, instead of arising from the innominate, it may be given off by the aortic arch, by the right common carotid, by either the right or left subclavian, or, in rare cases, by one of the branches of the subclavians.

Practical Considerations.—The *line* of the innominate artery is from the middle of the manubrium to the right sterno-clavicular joint. Its point of bifurcation would be crossed by a line drawn backward, just above the clavicle, through the interval between the sternal and clavicular portions of the sterno-mastoid muscle.

Aneurism of the innominate artery, often associated with aneurism of the aortic arch, causes pressure-symptoms easily explained by the chief relations of the vessel. They may be summarized as follows : 1. *Vascular*, *(a) arterial*, weakness or irregularity of the right radical pulse or of the right carotid or temporal pulse from interruption of the direct blood-current ; (*b*) *venous*, duskiness of the face and neck, especially of the right side, œdema of the eyelids, protrusion of the eyeballs, lividity of the lips, from pressure on the left innominate, deep jugular, and transverse veins lying between the vessel and the thoracic wall ; œdema of the right arm from subclavian pressure. 2. *Nervous*, cough and hoarseness or aphonia from involvement of the right recurrent laryngeal : dilatation or contraction of the pupil from pressure on the sympathetic ; hiccough from irritation of the phrenic ; pain, particularly severe on the right side of the neck and head, the same side of the chest, and down the right arm from pressure on the branches of the cervical and brachial plexuses. In addition, dyspnœa and dysphagia from compression of the trachea and œsophagus, and the appearance of a swelling at and above the right sterno-clavicular articulation, often obliterating the suprasternal depression, are characteristic symptoms.

In endeavoring to differentiate these aneurisms from those of the arch of the aorta it may be well to remember that the position of the innominate is above, to the right, and, in a way, cervico-thoracic, while that of the arch is on a lower level, is median or to the left, and is wholly thoracic.

Ligation.—Two skin incisions, each three inches in length, are made along the anterior edge of the sterno-mastoid muscle and the upper border of the inner third of the clavicle, uniting at an acute angle near the right-sterno-clavicular articulation. The sternal portion and the greater part of the clavicular portion of the sterno-mas-

toid muscle are divided just above their origin. The anterior jugular vein runs behind the sternal head, and is to be avoided or tied. The thyroid plexus of veins may appear in the wound, and should be tied or drawn out of the way. The sterno-hyoid and sterno-thyroid muscles are divided close to the sternum. The deep cervical fascia is divided in the line of the superficial wound. The common carotid artery should be found, its sheath opened, and the vessel traced down to the innominate bifurcation. The internal jugular vein may be much engorged and should be drawn outward. The innominate vein may protrude into the wound. Osteoplastic resection of the manubrium (Bardenheuer), or a median longitudinal division of that bone (Woolsey) with retraction of the edges, will facilitate the exposure of the vessel. The most important relations are to the outer side,—viz., the vagus, the pleura, and the right innominate vein. The left common carotid and trachea lie to the inner side. The needle should be passed from without inward. The ligature should be placed as high as possible, to leave room between it and the aorta for the formation of a satisfactory clot. It is well to ligate the common carotid and the vertebral at the same time, to lessen the risk of secondary hemorrhage on the distal side of the ligature.

The collateral circulation is carried on from the proximal or cardiac side of the ligature by (*a*) the first aortic intercostal; (*b*) the upper aortic intercostals; (*c*) the inferior phrenic branch of the abdominal aorta (within the diaphragm); (*d*) the deep epigastric (within the rectus sheath); (*e*) the vertebrals and internal carotids of the left side (within the cranium—circle of Willis); and (*f*) the branches of the left external carotid; anastomosing respectively with (*a*) the superior intercostal of the subclavian; (*b*) the intercostals of the internal mammary and the thoracic branches of the axillary; (*c*) the musculo-phrenic branch of the internal mammary; (*d*) the superior epigastric branch of the internal mammary; (*e*) the vessels in the right half of the circle of Willis; and (*f*) the branches of the right external carotid, all receiving their blood-supply from beyond—or to the distal side of—the ligature.

THE COMMON CAROTID ARTERIES.

The right common carotid artery arises from the innominate and the left one from the arch of the aorta (Fig. 690). Both pass directly upward in the neck, along the side of the trachea and larynx, and terminate opposite the upper border of the thyroid cartilage by dividing into the external and internal carotid arteries, their course being represented by a line drawn from a point midway between the angle of the jaw and the mastoid process to the sterno-clavicular articulation. Throughout its course neither of the common carotids gives off any branches, and they consequently have an almost uniform calibre, except towards their point of division, where they present a dilatation frequently continued into the internal carotid and usually becoming more marked with advancing age.

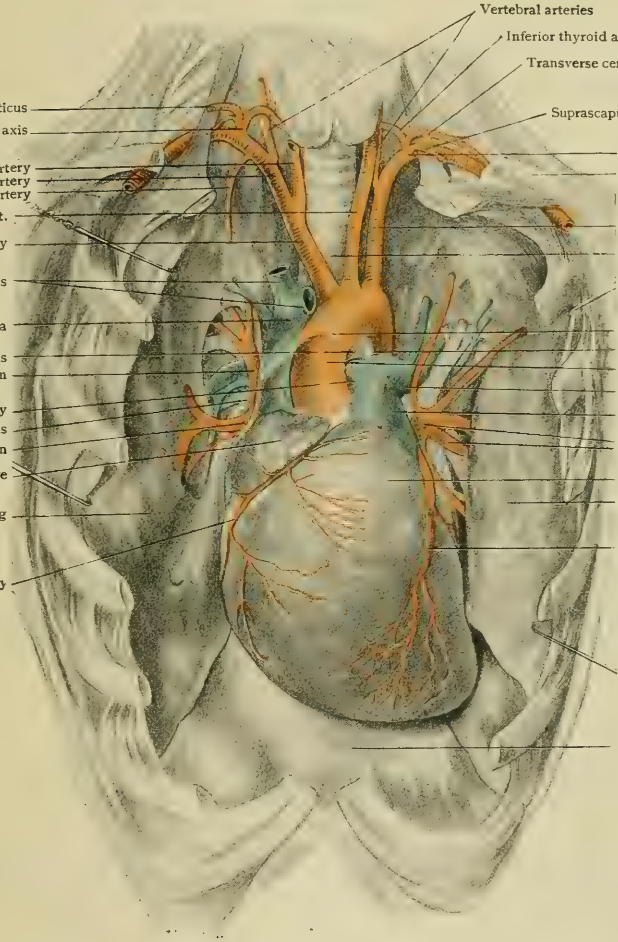
Relations.—The **left common carotid** lies in the thoracic cavity during the first part of its course, and in this respect differs from the right artery, whose origin from the brachio-cephalic is at the level of the sterno-clavicular articulation. This **thoracic portion** of the left common carotid is usually about 3 cm. (1¼ in.) in length, and is crossed obliquely in front, near its root, by the left innominate (brachio-cephalic) vein and by the cardiac branches of the pneumogastric nerve. It is separated from the sternum and the origin of the sterno-thyroid muscle by some fatty tissue which contains the remains of the thymus gland, and posteriorly it is in relation with the trachea below and higher up with the left recurrent laryngeal nerve. Below, to its right side and a short distance away, is the innominate artery; above it is in close relation with the trachea, while to its left and somewhat posteriorly are the left subclavian artery and the left pneumogastric nerve.

Throughout their **cervical portions** the relations of both arteries are identical. Each is enclosed within a fibrous sheath formed by the deep cervical fascia (page 550), the sheath also containing the internal jugular vein and the pneumogastric nerve, the vein lying lateral to the artery and the nerve between the two vessels, but in a plane slightly posterior to them. Extending downward for a variable distance upon the anterior surface of the sheath is the descending hypoglossal

nerve, and overlapping it to a certain extent is the sterno-cleido-mastoid muscle and, below, the sterno-hyoid and sterno-thyroid. At about the level of the cricoid cartilage of the larynx the artery is crossed obliquely by the omo-hyoid muscle, and higher up by the middle and superior thyroid, the lingual and sometimes the facial veins, and the sterno-mastoid branch of the superior thyroid artery.

Posteriorly the sheath rests upon the prevertebral fascia covering the longus colli and the rectus capitis anticus major muscles, and is in relation with the ganglionated cord of the sympathetic nervous system and its superior and middle cardiac branches. Lower down, opposite the sixth cervical vertebra, the branches of the

FIG. 690.



Dissection showing aortic arch and its branches; lungs have been pulled aside.

inferior thyroid artery pass behind it. Medially are the trachea and the œsophagus, together with the recurrent laryngeal nerve, the lobe of the thyroid gland, and, above, the larynx and the pharynx.

Variations.—The variations of the common carotid arteries have been sufficiently discussed in connection with the anomalies of the aortic arch (page 724).

Practical Considerations.—*Aneurism* of the common carotid artery is not very frequent. It most commonly occurs near the bifurcation (*a*) because of the slight dilatation normally existing there; (*b*) because there the vessel is more super-

ficial,—*i.e.*, least supported by overlying muscle; and (*c*) because of the increased resistance to the blood current at that point. It is seen oftener in the right carotid than in the left. *Pressure-symptoms*: *pain* in the side of the neck, face, and head in the distribution of the superficial cervical plexus of nerves; *duskiness* or *mottling* of the skin from pressure on the sympathetic; *dyspnœa* and *cough* from lateral deflection of the larynx and trachea; *defective vision*, *vertigo*, or *stupor* from pressure on the internal jugular; *hoarseness* or *aphonia* from implication of the recurrent laryngeal nerve; *dysphagia* from direct pressure on the œsophagus, or—possibly, together with *irregular heart action*, *vomiting*, or *asthmatic respiration*—from pressure on the pneumogastric.

Digital compression may be used in a case of stab wound or in the treatment of aneurism (*a*) by making pressure backward and outward beneath the anterior edge of the sterno-mastoid muscle at the level of the cricoid cartilage, so as to flatten out the artery against the transverse process of the sixth cervical vertebra (carotid tubercle) about two and a half inches above the clavicle. As the vertebral artery at this level enters its canal in the foramina of the transverse processes, it will probably escape pressure. The internal jugular vein is usually displaced laterally. The common carotid artery may also be effectually compressed in cases of wound (*b*) by grasping the anterior edge of the sterno-mastoid and the artery together between the thumb and fingers, or (*c*) by placing the thumb beneath the artery and the anterior edge of the muscle, and the fingers along its posterior edge. In all three of these methods it is necessary to flex the head and turn it a little towards the affected side so as fully to relax the sterno-mastoid.

Ligation.—It may be necessary to tie the common carotid in cases of (*a*) aneurism, including certain pulsating tumors of the orbit or scalp or within the cranium; (*b*) hemorrhage from wound of the neck, or from pharyngeal wound or ulceration; or (*c*) for the prevention of bleeding during some operations. Whenever ligation of the external carotid satisfactorily meets the indications, it is better to tie that vessel (*q.v.*), as the cerebral circulation is not thereby interfered with.

The lower portions of the common carotids on both sides of the neck are deeply seated; they are covered by three planes of muscles (the sterno-mastoid, sterno-hyoid, and sterno-thyroid); the inferior thyroid artery and recurrent laryngeal nerve run behind them on each side, and on the left side the internal jugular vein usually passes from without inward in front of the artery, which is also in close relation to the thoracic duct, the innominate artery, and the left innominate vein.

Two operations for ligation of the common carotid may be described: 1. The place of election for the application of a ligature is just *above the omo-hyoid muscle*, where the artery has become more superficial and is covered only by the skin, the platysma, the fasciæ, and the anterior edge of the sterno-mastoid. The skin incision—three inches in length—is made in the line of the vessel, the centre being placed opposite the anterior arch of the cricoid cartilage. It divides also the platysma. The deep fascia is divided, and the anterior edge of the sterno-mastoid is exposed and followed downward to the angle between it and the upper edge of the omo-hyoid muscle. The former muscle is then drawn outward, the latter downward, the descendens hypoglossi nerve avoided, the sterno-mastoid branch of the superior thyroid artery and the superior—and sometimes the middle—thyroid vein held aside or tied, and the sheath opened over the carotid compartment,—*i.e.*, well to the inner side,—so as to avoid injury to the larger internal jugular vein, which sometimes—as in cases of embarrassed respiration—bulges over the artery so as completely to obscure it. The needle should be passed from without inward to avoid injury to the vein, care, of course, being taken not to include the vagus.

2. *Below the omo-hyoid muscle* the skin incision—three inches in length—still follows the anterior border of the sterno-mastoid, beginning now a little below the lower border of the cricoid cartilage and ending just above the sterno-clavicular articulation. A second incision along the upper border of the clavicle is often advisable. The sterno-mastoid is drawn outward and the outer edge of the sterno-hyoid muscle exposed, and that muscle, with the sterno-thyroid, drawn downward and inward. Frequently the sternal portion of the sterno-mastoid, and occasionally the sterno-hyoid and sterno-thyroid muscles also, will require division if the ligature has

to be placed as near the root of the neck as possible. The internal jugular vein—especially on the left side—the inferior thyroid artery, and the recurrent laryngeal nerve must be avoided. The needle is passed from without inward.

The *collateral circulation* is carried on from the proximal or cardiac side through (*a*) the branches of the external carotid on the opposite side, (*b*) the inferior thyroid, (*c*) the profunda cervicis (from the superior intercostal and thus from the subclavian), (*d*) the internal carotid and the vessels of the opposite segment of the circle of Willis, and (*e*) the vertebral, by anastomosing respectively with (*a*) the external carotid branches, (*b*) the superior thyroid, (*c*) the princeps cervicis (from the occipital), and (*d*) and (*e*) the vessels of the circle of Willis on the affected side.

THE EXTERNAL CAROTID ARTERY.

The external carotid artery (**a. carotis externa**) (Figs. 692, 693) arises from the common carotid at about the level of the upper border of the thyroid cartilage—a level which corresponds to the body of the fourth cervical vertebra. Thence it is directed upward and slightly backward towards the angle of the jaw, where it enters the substance of the parotid gland and continues upward in that structure to just below the root of the zygoma. Here it gives rise to a large branch, the internal maxillary, and is then continued upward over the root of the zygoma upon the side of the skull, this terminal portion of it being termed the *superficial temporal artery*.

Relations.—In the first portion of its course the external carotid lies in the superior carotid triangle (page 548), and is there crossed by the hypoglossal nerve and the facial vein. Higher up it passes beneath the posterior belly of the digastric and the stylo-hyoid muscles and also beneath the temporo-maxillary vein, and enters the substance of the parotid gland. Posteriorly it is separated from the internal carotid artery by the stylo-glossus and stylo-pharyngeus muscles and the glosso-pharyngeal nerve; the internal carotid artery lies laterally to it at its origin; internally it is in relation with the inferior and middle constrictors of the pharynx and the superior laryngeal nerve.

Branches.—From the anterior surface of the external carotid arise, from below upward, (1) the *superior thyroid*, (2) the *lingual*, (3) the *facial*, and (4) the *internal maxillary arteries*. From its posterior surface, in the same order of succession, arise (5) the *ascending pharyngeal*, (6) the *sterno-mastoid*, (7) the *occipital*, (8) the *posterior auricular arteries*. Finally, (9) the *superficial temporal artery* is to be regarded as a branch which is the continuation upward of the main stem.

Variations.—Occasionally the external carotid artery is absent, its branches arising from the common carotid, which is continued directly into the internal carotid. The number of its branches may be reduced by certain of them, the lingual and facial, for instance, arising by a common stem, or they may be increased by the occurrence of various accessory branches passing to regions supplied by the regular ones.

Practical Considerations.—The external carotid is rarely the subject of *aneurism*, except as a result of trauma. The tumor is situated below the angle of the jaw. Pressure on the hypoglossal and glosso-pharyngeal nerves and on the internal jugular vein causes various symptoms which are not usually definitely diagnostic. In one case there was unilateral atrophy of the tongue (Heath) probably from involvement of the hypoglossal. If the aneurism is situated near the origin of the vessel, it may be indistinguishable from aneurism of the common carotid at its usual location, just below the bifurcation. The vessel is not infrequently tied for wound of the neck, for aneurism of one of its branches, and occasionally as a preliminary to certain operations, as excision of the superior maxilla or removal of a malignant tonsillar or parotid tumor. In cases of stab or cut-throat wound it is better, when possible, to find and tie both ends of the bleeding vessel, as the free anastomosis between the branches of the two external carotids renders a recurrence of hemorrhage probable after ligation of the main trunk.

Ligation.—That part of the line for the common carotid extending from the level of the angle of the lower jaw to that of the middle of the thyroid cartilage is the

line for the skin incision. The artery is usually tied below the digastric muscle—*i.e.*, in the superior carotid triangle (page 548)—and between the origins of the superior thyroid and the lingual arteries—because that is the longest interval without branches. After the skin, superficial fascia, platysma, and deep fascia have been divided, the anterior edge of the sterno-mastoid cleared and drawn outward at the lower portion of the wound, and the facial, lingual, or superior thyroid veins—if they present—drawn aside or tied and cut, the posterior belly of the digastric muscle above should be identified. Just beneath it the hypoglossal nerve crosses the artery, and a little lower—about the middle of the incision—the tip of the greater cornu of the hyoid bone may be felt. At this level—above the origin of the superior thyroid and below that of the lingual—the artery lies just to the inner side of the internal carotid (but somewhat superficial to it) and of the internal jugular vein, and has the superior laryngeal nerve in close relation behind it.

The internal carotid has been tied at this level by mistake for the external carotid. To avoid this it should be remembered that the external carotid (*a*) is more anterior; (*b*) is more superficial; (*c*) is usually smaller, especially in the young; (*d*) gives off branches; (*e*) is close to the tip of the hyoid bone; (*f*) is in contact with the hypoglossal nerve; and (*g*) that compression of the isolated vessel arrests the temporal and facial pulses. The needle is passed from without inward to avoid the internal jugular.

The ligature has been applied just below the parotid gland—*i.e.*, *above* the digastric muscle. The incision (on the same line) should extend from the lobe of the ear to the hyoid bone, the sterno-mastoid should be drawn outward, the posterior belly of the digastric and the stylo-hyoid muscle downward, and the parotid upward and inward.

The *collateral circulation* is carried on from the cardiac side through (*a*) the branches of the opposite external carotid; (*b*) the inferior thyroid on the affected side; (*c*) the branches of the ophthalmic of the same side; and (*d*) the profunda cervicis, anastomosing respectively with (*a*) the branches of the ligated external carotid; (*b*) the superior thyroid; (*c*) the facial (from the same vessel—the external carotid); and (*d*) the princeps cervicis.

1. **The Superior Thyroid Artery.**—The superior thyroid artery (**a. thyroidea superior**) (Fig. 692) arises from the anterior surface of the external carotid, a short distance above its origin, and is at first directed almost horizontally anteriorly, but soon turns downward and, passing over the superior laryngeal nerve and beneath the omo-hyoid and thyro-hyoid muscles, breaks up into a number of branches which enter the substance of the thyroid gland. It possesses always a calibre of considerable size, but varies directly according to the size of the gland, and inversely according to the amount of blood reaching the gland from other sources. It anastomoses abundantly with its fellow of the opposite side and with the inferior thyroid branch of the subclavian.

Branches.—From its **horizontal portion** are given off—

(*a*) An **infrahyoid branch** (**ramus hyoideus**), which passes along the lower border of the hyoid bone, supplying the muscles inserting into that bone.

(*b*) A **sterno-mastoid branch** (**ramus sternocleidomastoideus**), always small and occasionally wanting, which passes downward and backward across the sheath enclosing the common carotid to enter the substance of the sterno-cleido-mastoid muscle.

(*c*) A **superior laryngeal branch** (**a. laryngea superior**), which passes forward and downward beneath the thyro-hyoid muscle and, piercing the thyro-hyoid membrane along with the superior laryngeal nerve, is distributed to the intrinsic muscles and mucous membrane of the larynx.

From its **descending portion** it gives off—

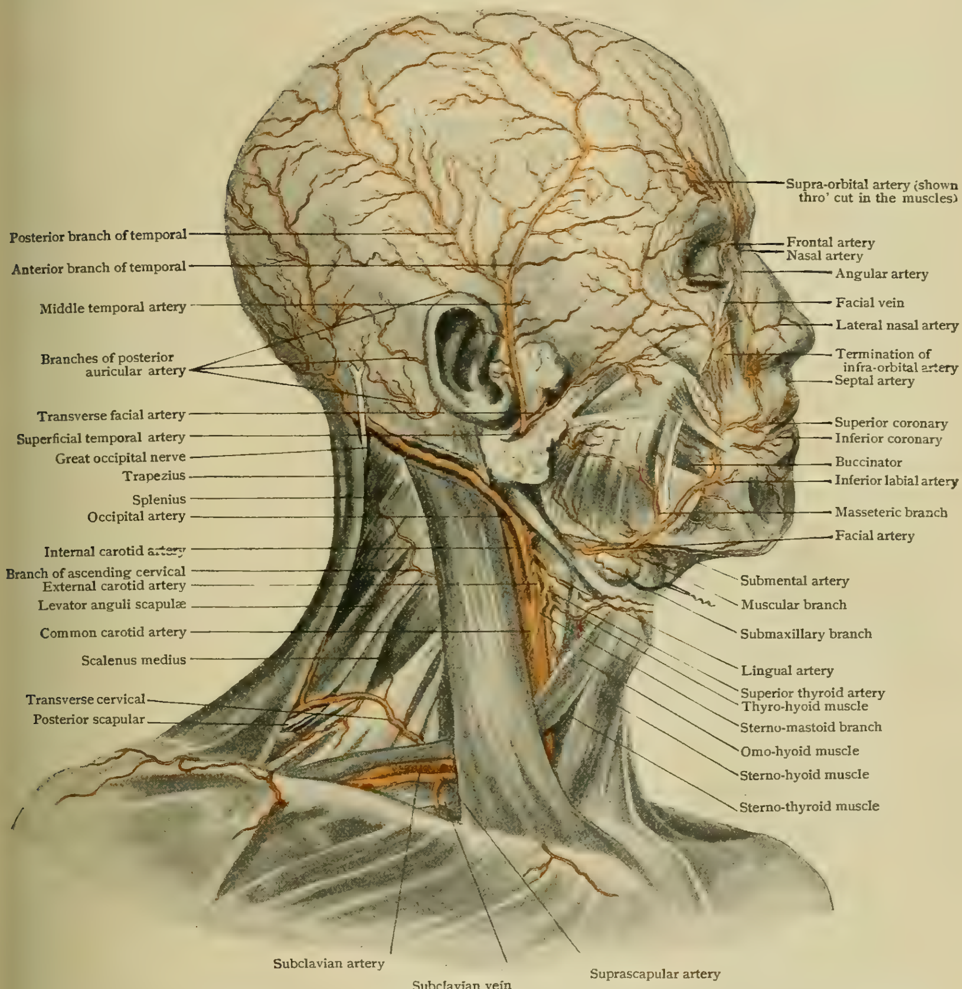
(*d*) The **crico-thyroid branch** (**ramus cricothyroideus**), usually of small size, which passes horizontally forward over the crico-thyroid membrane and anastomoses with its fellow of the opposite side, giving off branches which perforate the membrane and are distributed to the muscles and mucous membrane of the lower part of the larynx.

Variations.—The superior thyroid may give origin to both the ascending pharyngeal and the ascending palatine. The crico-thyroid not infrequently arises from the superior laryngeal, and may appear to be the main stem of that artery, and the superior laryngeal may arise directly from the external carotid.

Practical Considerations.—The superior thyroid artery or one of its branches is frequently divided in cut-throat wounds. The sterno-mastoid branch may have to be tied in the operation of ligation of the common carotid at the place of election and the crico-thyroid branch during the performance of laryngotomy.

Ligation.—The skin incision, two inches in length, with its centre opposite the thyro-hyoid space, is made along the carotid line. After the superior thyroid veins have been dealt with and the external carotid has been recognized, the vessel may most easily be found in the sulcus between the upper border of the thyroid cartilage

Fig. 691.



Superficial dissection, showing arteries of neck, face and scalp.

and the great vessels, where for a short distance it is superficial and runs almost horizontally.

The needle should be passed from above downward with the point directed somewhat towards the mid-line. The close proximity posteriorly of the superior laryngeal nerve should be remembered.

2. **The Lingual Artery.**—The lingual artery (**a. lingualis**) (Fig. 692) usually arises from the anterior surface of the external carotid, between the origins of the superior thyroid and the facial, although it is sometimes given off from a trunk

common to it and one or other of these arteries, especially the facial. In the first part of its course it passes forward and slightly upward and inward towards the tip of the lesser cornu of the hyoid bone, and is crossed by the posterior belly of the digastric and the stylo-hyoid muscles and by the hypoglossal nerve. On reaching the posterior border of the hyo-glossus, it passes beneath that muscle and is continued almost directly forward beneath the mucous membrane covering the under surface of the tongue and between the genio-hyo-glossus and the inferior lingualis muscles. In this terminal portion it has a sinuous course, and is frequently termed the **ranine artery** (a. **profunda linguae**); it gives branches to the adjacent muscular substance and mucous membrane of the tongue, and near its termination anastomoses with its fellow of the opposite side.

Branches.—(*a*) The **suprahyoid branch** (**ramus hyoideus**), given off from the first portion, passes horizontally forward over the hyoid bone, sending branches to the muscles which are inserted into that bone from below.

(*b*) The **dorsal lingual branch** (**rami dorsales linguae**), from the second portion, arises under cover of the posterior border of the hyo-glossus and, passing upward medial to the stylo-glossus, breaks up into branches which are distributed to the mucous membrane of the dorsum of the tongue, as far back as the epiglottis, and also to the tonsil. Occasionally a branch unites with a corresponding one from the artery of the opposite side, immediately in front of the foramen cæcum, and is continued forward in the median line, immediately beneath the mucous membrane of the dorsum of the tongue, as far as the tip.

(*c*) The **sublingual branch** (**a. sublingualis**) is given off near the anterior border of the hyo-glossus muscle and runs forward in the same plane as the ranine artery, but on a lower level, resting upon the mylo-hyoid muscle and lying between the genio-hyoid laterally and the genio-hyo-glossus medially. It is accompanied by the submaxillary (Wharton's) duct, which lies upon its medial side, and it terminates in the sublingual gland, also sending branches to the neighboring muscles and to the alveolar border of the mandible.

Anastomoses.—The various branches of the lingual artery anastomose extensively with their fellows of the opposite side. The anastomoses of the two aa. dorsales linguæ take place, however, only through exceedingly fine twigs, so that the tongue may be divided longitudinally in the median line without any great loss of blood, except towards the tip, where a larger anastomosis of the ranine arteries occurs. In addition to these contra-lateral anastomoses, the lingual also anastomoses through its suprahyoid branch with the infrahyoid of the superior thyroid artery, through its sublingual branch with the submental branch of the facial, and through the a. dorsalis linguæ with the various tonsillar arteries.

Variations.—The lingual artery sometimes arises from a common trunk with the facial, and it has been observed to terminate at the root of the tongue, being replaced in the rest of its course by branches from the internal maxillary or by the submental branch of the facial. The sublingual branches are not infrequently lacking, being replaced by branches of the submental, and, in addition to its normal branches, the main artery may give rise to a superior laryngeal and an accessory superior thyroid branch.

Practical Considerations.—The lingual artery is tied most frequently as a preliminary to excision of the whole or part of the tongue, but one or both arteries may be ligated to stop bleeding following wound or malignant ulceration of that organ, or in an effort to arrest growth by cutting off blood-supply, as in cases of cancer of the tongue or of macroglossia.

Ligation.—The artery is for convenience divided into three portions, the *first* between its origin—about opposite the greater cornu of the hyoid—and the posterior edge of the hyo-glossus muscle, lying upon the middle constrictor of the pharynx; the *second* beneath the hyo-glossus muscle, lying upon the genio-glossus; the *third*, (*ranine*) from the anterior border of the hyo-glossus along the under surface of the tongue to its termination.

The place of election is in the second part. The skin incision, two inches in length, curved, with the concavity upward, begins a half-inch below and external to the mandibular symphysis and ends a little below and internal to the point where the facial artery crosses the lower edge of the inferior maxilla; its centre is just above the greater cornu of the hyoid. If the incision is carried too far backward,

the facial vein may be cut. The remainder of the operation may be described as if it were done in four stages. 1. That portion of the deep fascia constituting the anterior layer of the capsule of the submaxillary gland is divided in the line of the incision, the lower edge of the gland exposed, and the gland itself cleared and elevated over the lower jaw, with due care to avoid injury to the facial artery which passes through its substance and the facial vein which runs upon its surface. 2. The thin posterior leaf of the capsule of the gland being divided, the white, shining aponeurotic loop attaching the digastric tendon to the greater cornu of the hyoid will be seen. The tendon near the bone or the digastric aponeurosis should be fixed by a blunt hook or tenaculum and drawn downward and towards the surface. 3. After the division of the posterior layer of the capsule of the submaxillary gland, the posterior edge of the mylo-hyoid muscle, the fibres running upward and slightly backward, can be recognized at the anterior angle of the wound and should be clearly defined. 4. The hypoglossal nerve separates from the artery at the posterior border of the hyo-glossus muscle, where the vessel disappears to run between that muscle and the middle constrictor. The nerve, accompanied by the ranine vein, runs almost horizontally across the surface of the hyo-glossus, and in its turn disappears under the edge of the mylo-hyoid muscle. It will have been brought into view when the submaxillary gland has been raised, the posterior layer of its capsule divided, and a little fatty connective tissue picked away. In the irregular triangle formed by the nerve above, the mylo-hyoid anteriorly, and the posterior belly and tendon of the digastric posteriorly, the lingual artery runs *beneath* the hyo-glossus muscle and near the apex of the triangle—*i.e.*, near the hyoid bone. The nerve and vein, which are on a slightly higher level—a few millimetres—having been raised and the fibres of the hyo-glossus divided parallel with the hyoid and just above it, the artery will be brought into view.

In ligation of the lingual for carcinoma of the tongue, the state of the salivary gland, which varies in size, in density, and in the closeness of its attachments, is the main element of uncertainty (Treves).

3. **The Facial Artery.**—The facial artery (**a. maxillaris externa**) (Fig. 691) arises usually a short distance above the lingual, from the anterior surface of the external carotid. It passes at first forward and slightly upward, lying beneath the posterior belly of the digastric and the stylo-hyoid muscles and the hypoglossal nerve, and is then continued almost horizontally forward in a groove in the submaxillary gland. When it reaches the level of the anterior border of the masseter muscle, it assumes a vertical direction and passes over the ramus of the mandible, and is then continued in a sinuous course obliquely across the face towards the naso-labial angle, resting upon the buccinator and levator anguli oris muscles, and being crossed by the risorius and zygomatic muscles and by some branches of the facial nerve. Arrived at the naso-labial angle, it again takes an almost vertical course, passing upward beneath (or sometimes over) the levator labii superioris and the levator labii superioris alæque nasi towards the inner angle of the orbit, where it terminates by anastomosing with the nasal branch of the ophthalmic artery. This terminal vertical portion of the vessel is usually termed the *angular artery* (**a. angularis**).

Branches.—The branches of the facial artery (Figs. 691, 693) may be arranged in two groups according to their origin from the cervical or facial portions of the artery.

From the **cervical portion** arise: (*a*) The **ascending palatine branch** (**a. palatina ascendens**), a small artery which passes upward between the stylo-glossus and stylo-pharyngeus muscles, to which it sends branches, and then comes to lie upon the outer surface of the superior constrictor of the pharynx. It terminates by sending branches to the soft palate, the tonsil, and the Eustachian tube.

(*b*) The **tonsillar branch** (**ramus tonsillaris**) is another small branch which passes vertically upward. It arises close to the ascending palatine and, passing over the stylo-glossus muscle, pierces the superior constrictor of the pharynx to be distributed to the tonsil.

(*c*) The **glandular branches** (**rami glandulares**), two or three in number, are distributed to the submaxillary gland.

(*d*) The **submental branch** (**a. submentalis**) arises just before the artery bends upward over the mandible, and continues onward in the horizontal course followed by the facial,

through the submaxillary gland. It passes forward upon the mylo-hyoid muscle, close to its origin, until it reaches the insertion of the anterior belly of the digastric, when it passes upward upon the ramus of the mandible to supply the depressor labii inferioris and to anastomose with the mental branches of the inferior dental artery and with the inferior labial branches of the facial. It sends branches to the muscles in its vicinity and also to the integument, and branches perforate the mylo-hyoid muscle to anastomose with the sublingual branches of the lingual.

From the facial portion. (*e*) The **masseteric branches** arise from the posterior surface of the artery and are directed upward to supply the masseter muscle and to anastomose with branches of the internal maxillary and transverse facial arteries.

(*f*) The **inferior labial branch** (**a. labialis inferior**) passes forward along the outer surface of the horizontal ramus of the mandible, supplying the depressor anguli oris, the depressor labii inferioris, and the integument, and anastomosing with the mental branches of the inferior dental and submental arteries.

(*g*) The **inferior coronary artery** passes forward in the substance of the lower lip between the mucous membrane and orbicularis oris, supplying the latter, and terminates by anastomosing with its fellow of the opposite side.

(*h*) The **superior coronary artery** (**a. labialis superior**) has the same course and relations in the upper lip that the inferior coronary has in the lower one. It anastomoses with its fellow of the opposite side, and near its termination usually sends a small branch upward to the septum of the nose, the *a. septi narium.*

(*i*) The **lateral nasal** takes its origin just as the artery reaches the naso-labial angle; it passes forward over the ala of the nose, supplying its muscles and integument.

(*j*) The **angular artery** (**a. angularis**) is the terminal portion of the facial artery beyond the naso-labial angle. It passes directly upward in the angle between the nose and the cheek, and gives branches to the adjacent muscles, the lachrymal sac, and the orbicularis palpebrarum, anastomosing with the nasal branch of the ophthalmic artery and with the infra-orbital branch of the internal maxillary.

Anastomoses.—The facial artery, by means of its facial branches and the submental arteries, makes abundant anastomoses with its fellow of the opposite side. In addition, it is connected with other branches of the external carotid; with the dorsalis linguæ and submental branches of the lingual by its tonsillar and inferior labial branches respectively; with the descending palatine, infra-orbital branches, and mental branches of the internal maxillary by its tonsillar, angular, and inferior labial branches; and with the transverse facial branch of the superficial temporal by its masseteric branches. Finally, it is connected with the ophthalmic branch of the internal carotid by the angular artery.

Variations.—The facial artery may arise by a trunk common to it and the lingual, or it may arise above the level of the angle of the jaw. Quite frequently it does not extend upon the face beyond the angle of the mouth, being replaced in the upper part of its course by branches from the transverse facial or internal maxillary artery.

The ascending palatine branch frequently arises directly from the external carotid, or it may take its origin from the ascending pharyngeal or from the occipital, and the tonsillar is frequently a branch of it. The submental branch may be greatly reduced in size or even absent, being replaced in whole or in part by the sublingual, these two arteries being inversely proportionate to each other so far as their development is concerned.

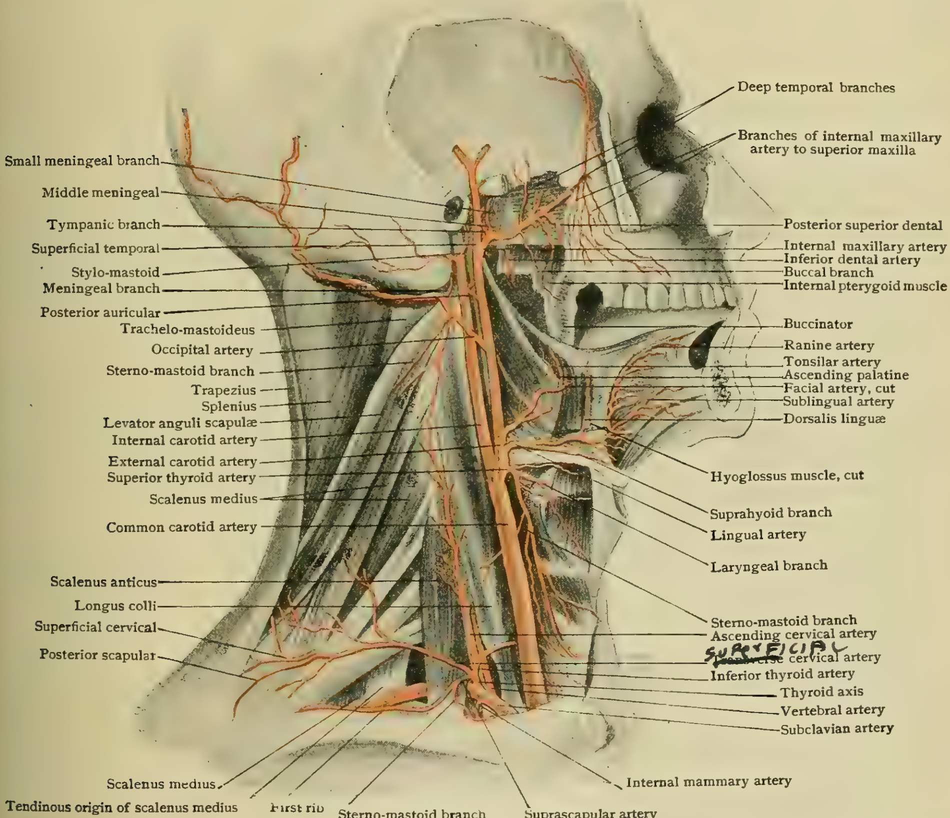
Practical Considerations.—The facial artery may require ligation on account of division of one of its branches, as the coronary, but whenever direct ligation of the wounded vessel is possible, it is preferable on account of the very free anastomosis between the branches of opposite sides, leading usually, after ligation of the main trunk, to recurrence of the hemorrhage. In bleeding after tonsillotomy (page 1608), either the tonsillar branch of the facial or the main vessel (where it runs between the posterior belly of the digastric and the stylo-glossus muscles) may be involved; but as the blood may also be furnished by the ascending pharyngeal, ligation of the external carotid itself rather than of the facial would be more likely to be efficient.

Ligation.—(*a*) The *cervical portion* of the vessel may be reached through an incision like that for the lingual, placed a little higher, and not extending so far anteriorly. When the submaxillary gland is drawn upward, the artery will be drawn with it and made prominent. This portion may also be reached near its origin by uncovering the external carotid (*q.v.*) and identifying the vessel where it runs

between the posterior belly of the digastric above and the hypoglossal nerve below. (*b*) The *facial portion* is easily exposed where it crosses the mandible at the anterior border of the masseter, either by a vertical cut parallel with that muscle and the artery or by a horizontal cut crossing the vessel and placed under the inferior margin of the jaw so as to leave the scar in an inconspicuous position. Beneath the skin and the superficial fascia the platysma and deep fascia are the only structures that require division. The vein lies in the groove between the artery and the edge of the masseter.

4. **The Internal Maxillary Artery.**—The internal maxillary (**a. maxillaris interna**) (Fig. 692) is a large branch which arises from the anterior surface of the

FIG. 692.



Deeper dissection, showing carotid and subclavian arteries.

external carotid, opposite the neck of the mandible. It passes forward with a flexuous course, lying at first between the neck of the mandible and the spleno-mandibular ligament, and then passing either between the two pterygoid muscles, in which case it crosses the inferior dental and lingual nerves, or else over the external surface of the external pterygoid, between that muscle and the temporal. It then passes between the two heads of the external pterygoid, in the one case passing from below upward and in the other from without inward, and enters the spheno-maxillary fossa, in which it is directed upward and inward towards the spheno-palatine foramen, which it traverses under the name of the spheno-palatine artery.

Branches.—For convenience in description it is customary to regard the internal maxillary artery as consisting of three portions. Its first, or *mandibular portion*, is that which lies inter-

nal to the neck of the mandible; the second, or *pterygoid portion*, is that which traverses the zygomatic fossa, and is in relation with the pterygoid muscles; and the third, or *spheno-maxillary portion*, extends from where it passes between the two heads of the external pterygoid muscle to its entrance into the spheno-palatine foramen. Of the sixteen named branches arising from the internal maxillary artery, five arise from the first portion, five from the second, and six from the third.

From the first or mandibular portion arise (1) the *deep auricular*, (2) the *tympanic*, (3) the *middle meningeal*, (4) the *small meningeal*, and (5) the *inferior dental* arteries.

(*a*) The **deep auricular** (**a. auricularis profunda**) is a small branch which passes behind the temporo-mandibular articulation, to which it sends branches, and perforates the anterior wall of the external auditory meatus to supply the skin lining that passage and the outer surface of the tympanic membrane.

(*b*) The **tympanic** (**a. tympanica anterior**), also a small branch, passes upward, giving off branches to the temporo-mandibular articulation, and enters the Glaserian fissure. Thence it traverses the iter chordæ anterius along with the chorda tympani, and reaches the middle ear, to whose mucous membrane it is distributed, anastomosing with the tympanic branches of the stylo-mastoid artery.

(*c*) The **middle meningeal** (**a. meningea media**) is the largest of all the branches. It ascends vertically towards the base of the skull and enters the cranium by the foramen spinosum, and, after passing outward and upward for a short distance upon the great wing of the sphenoid, divides into an anterior and a posterior terminal branch, which ramify over the surface of the dura and supply nearly the whole of its lateral and superior surfaces, making abundant anastomoses with the vessel of the opposite side. The *anterior branch*, the larger of the two terminal branches, passes obliquely forward over the greater wing of the sphenoid, crosses the anterior inferior angle of the parietal, and then ascends along the anterior border of that bone almost to the superior longitudinal sinus, sending off numerous branches. The *posterior branch* passes backward and upward over the squamous portion of the temporal bone, and then over the posterior part of the parietal bone, giving off numerous branches which pass upward as far as the superior longitudinal sinus and backward as far as the lateral sinus. In addition to these terminal branches, the main stem within the cranium also gives origin to (*aa*) a *petrosal branch* (**a. petrosus superficialis**) which enters the hiatus Fallopii and anastomoses with the terminal portion of the stylo-mastoid arteries; to (*bb*) *Gasserian branches*, minute twigs which pass to the Gasserian ganglion and the fifth nerve; to (*cc*) a *tympanic branch* (**a. tympanica superior**) which descends through the petro-squamous suture to the mucous membrane of the middle ear and the mastoid cells; and, finally, to (*dd*) an *orbital branch*, a small vessel that passes into the orbit through the outermost portion of the sphenoidal fissure and anastomoses with the lachrymal branch of the ophthalmic.

(*d*) The **small meningeal** (**r. meningeus accessorius**) is an inconstant branch, sometimes arising from the middle meningeal. It passes upward along the mandibular division of the fifth nerve, and enters the cranium through the foramen ovale to be distributed to the Gasserian ganglion and the dura mater in its neighborhood.

(*e*) The **inferior dental** (**a. alveolaris inferior**) is given off from the lower surface of the artery and descends along with the inferior dental nerve to the mandibular foramen. Before reaching the foramen it gives off (*aa*) a *lingual branch*, which accompanies the lingual nerve to the tongue, and (*bb*) a *mylo-hyoid branch* (**ramus mylohyoideus**), accompanying the mylo-hyoid nerve to the muscle of that name. Entering the mandibular foramen, it traverses the mandibular canal, giving off branches to the roots of the lower teeth as it passes them, and finally emerges at the mental foramen as (*cc*) the *mental artery* (**a. mentalis**), supplying the neighboring muscles and integument and anastomosing with the submental and inferior labial branches of the facial. Just before issuing from the mental foramen it gives off (*dd*) an *incisive branch* which distributes twigs to the incisor teeth.

From the second, or pterygoid portion, arise branches distributed chiefly to the adjacent muscles; they are (1) the *masseteric*, (2) the *deep temporal*, (3 and 4) the *internal* and *external pterygoid*, and (5) the *buccal* artery.

(*f*) The **masseteric branch** (**a. masseterica**) passes with the corresponding nerve through the sigmoid notch of the mandible to enter the deep surface of the masseter.

(*g*) The **deep temporal branches** are two in number, the anterior and the posterior. The *posterior* branch (**a. temporalis profunda posterior**) arises close to or in common with the masseteric, while the *anterior* one (**a. temporalis profunda anterior**) is given off near the termination of the pterygoid portion of the artery. They both pass upward between the temporal muscle and the bone, supplying the muscle and anastomosing with the middle temporal branch of the temporal artery.

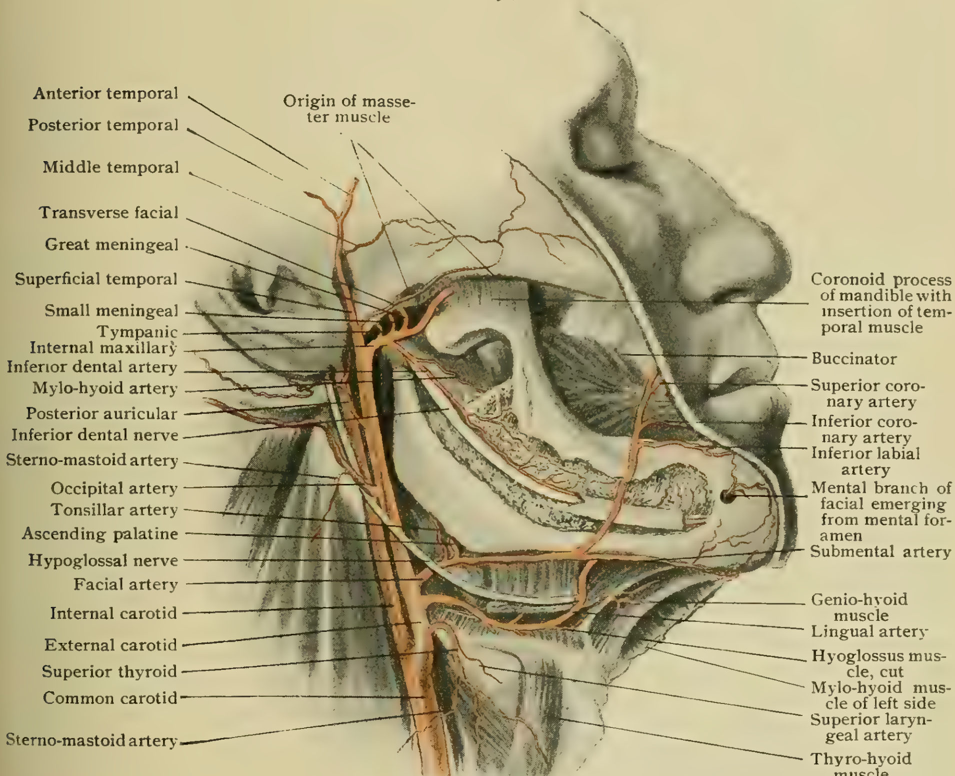
(*h* and *i*) The **internal and external pterygoid branches** (**rami pterygoidei**) are short and variable in number. They pass directly into the muscles of the same names.

(*j*) The **buccal branch** (**a. buccinatoria**) passes downward and forward with the buccal nerve along the anterior border of the tendon of the temporal muscle, and supplies the buccinator muscle and the mucous membrane of the mouth.

From the **third** or **spheno-maxillary portion** arise (1) the *alveolar*, (2) the *infraorbital*, (3) the *descending palatine*, (4) the *Vidian*, (5) the *pterygo-palatine*, and (6) the *spheno-palatine*.

(*k*) The **alveolar branch** (**a. alveolaris superior posterior**) descends upon the tuberosity of the maxilla, giving off branches which penetrate small foramina in that bone and are distributed to the molar and premolar teeth and the gums of the upper jaw and to the mucous membrane lining the antrum of Highmore. The main stem terminates upon the tuberosity of the maxilla by breaking up into a plexus with which branches from the buccal artery unite.

FIG. 693.



External carotid, internal maxillary and inferior dental arteries; condyle and outer table of mandible have been removed.

(*l*) The **infraorbital artery** (**a. infraorbitalis**) frequently arises in common with the alveolar. It passes forward and upward through the spheno-maxillary fossa and the spheno-maxillary foramen to traverse the infraorbital groove and canal along with the infraorbital nerve. In this part of its course it gives off (*aa*) *orbital branches*, distributed to the adipose tissue of the orbit and to the neighboring muscles of the eye, and (*bb*) *anterior dental branches* (**aa. alveolares superiores anteriores**) which pass down the anterior wall of the antrum of Highmore, along with the anterior and middle superior dental nerves, to supply the mucous membrane lining the antrum and the canine and incisor teeth of the upper jaw. The main stem emerges upon the face at the infraorbital foramen and divides into (*cc*) *palpebral*, (*dd*) *nasal*, and (*ee*) *labial branches*, whose distribution is indicated by their names, and which anastomose with the nasal and lachrymal branches of the ophthalmic artery, the transverse facial branch of the superficial temporal, and the superior coronary and angular branches of the facial.

(*m*) The **descending palatine artery** (**a. palatina descendens**) accompanies the anterior palatine nerve from the spheno-palatine ganglion through the posterior palatine canal, and, on its

emergence from the posterior palatine foramen, divides into an anterior and a posterior branch. The former passes forward beneath the mucous membrane of the hard palate, which it supplies, and at the anterior palatine foramen anastomoses with the spheno-palatine artery; the latter passes backward to supply the soft palate and the tonsil, anastomosing with the ascending palatine branch of the facial.

(*n*) The **Vidian artery** (**a. canalis pterygoidei**) is a small branch which passes backward along the Vidian nerve through the Vidian canal, and sends branches to the roof of the pharynx and to the Eustachian tube.

(*o*) The **pterygo-palatine artery** (**a. palatina major**) is also a somewhat slender branch. It passes backward through the pterygo-palatine foramen along with the pharyngeal nerve from the spheno-palatine ganglion, and supplies the roof of the pharynx, the Eustachian tube, and the mucous membrane lining the sphenoidal cells.

(*p*) The **spheno-palatine artery** (**a. sphenopalatina**) is the terminal branch of the internal maxillary. It passes into the nasal cavity through the spheno-palatine foramen along with the spheno-palatine nerve from the spheno-palatine ganglion. Shortly after traversing the foramen it divides into an internal and an external branch. The *internal branch*, sometimes termed the *naso-palatine*, passes transversely across the roof of the nasal cavity to reach the septum, upon which it passes downward and forward, giving off numerous branches which anastomose to form a rich net-work beneath the mucous membrane of the septum. It finally reaches the anterior palatine foramen, where it anastomoses with the anterior branch of the descending palatine. Throughout its course it is accompanied by the naso-palatine nerve. The *external branch* ramifies downward and forward over the lateral wall of the nasal fossa, forming a rich plexus beneath the mucous membrane lining the meatuses and the turbinate bones.

It will be observed that all the branches arising from the first and third portions of the internal maxillary artery traverse bony canals or foramina, while those of the second portion do not, but are distributed directly to muscles.

Anastomoses.—The communications of the internal maxillary artery are with the branches of the artery of the opposite side, with other branches of the artery of the same side, with other branches of the external carotid, and with branches of the internal carotid. The most abundant anastomoses with the artery of the opposite side are made through the branches of the middle meningeal; the alveolar branch anastomoses with the dental branches of the infraorbital of the same side and with the buccal artery, and the anterior branch of the descending palatine makes a large anastomosis with the naso-palatine branch of the spheno-palatine at the anterior palatine foramen. The other branches of the external carotid with which anastomoses are made are the facial, the temporal, and the posterior auricular; the facial communicates by means of its submental and inferior labial branches with the mental branch of the inferior dental, by its superior coronary and angular branches with the terminal branches of the infraorbital, by its superior coronary with branches of the naso-palatine, and by its ascending palatine with branches of the descending palatine. The deep temporal arteries anastomose with branches of the superficial temporal and the infraorbital with the transverse facial branch of the same artery; while the posterior auricular communicates by means of its stylo-mastoid branch with the tympanic branch and with the petrosal branch of the middle meningeal.

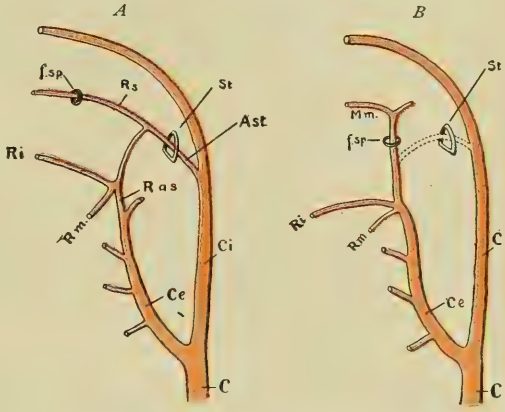
Of the anastomoses with the internal carotid arteries the most important are those between the orbital branch of the middle meningeal and the lachrymal artery, between the terminal branches of the infraorbital and the terminal branches of the ophthalmic, and between the spheno-palatine branches and the ethmoidal arteries.

Variations.—In the early stages of development the main portion of the internal maxillary is represented by a stem which arises from the internal carotid (Tandler). This is known as the *a. stapedia* (Fig. 694, *Ast*), since it traverses the middle ear, passing through the foramen of the stapes (*st*); it makes its exit from the middle ear by the Glaserian fissure and divides into two stems, one of which (*Rs*) passes through the foramen spinosum (*fsp*) and is distributed to the supraorbital region, while the other divides into two branches which, from their distribution, are termed the infraorbital (*Ri*) and the mandibular (inferior dental) (*Rm*). A branch (*Ras*) arises later from the external carotid which anastomoses with the lower stem where it divides into the two branches just mentioned, and the main stem of the stapedius disappears, except in its distal portion, which persists as the tympanic branch of the internal maxillary, which frequently arises in the adult from the middle meningeal instead of directly from the internal maxillary. By these changes, as may be seen from the accompanying diagrams, the adult internal maxillary is formed, the supraorbital branch becoming the middle meningeal (*Mm*) and the mandibular branch the inferior dental, while the infraorbital branch (*Ri*) becomes the main stem of the artery from which the remaining branches gradually develop.

In correspondence with this history, a persistence of the stapedial artery is occasionally found; but the majority of the usual variations of the internal maxillary are due to the secondary anastomoses which its branches make with other vessels. Thus, by an enlargement of the anastomoses between the middle meningeal and the branches of the ophthalmic artery, that vessel or some of its branches, notably the lachrymal, may come to arise from the middle meningeal (page 749). And, similarly, by the anastomoses with the facial or transverse facial arteries, the terminal branches of the infraorbital may be transferred to those vessels, the infraorbital itself stopping in the middle of the infraorbital groove.

5. **The Ascending Pharyngeal Artery.** — The ascending pharyngeal artery (**a. pharyngea ascendens**) (Fig. 695) differs from all the other branches of the external carotid by its vertical course. It is a comparatively small stem which arises close to or immediately at the origin of the external carotid and passes upward, at first between that vessel and the internal carotid, and later between the internal carotid and the internal jugular vein.

Fig. 694.



Diagrams illustrating development of internal maxillary artery; *A*, early stage; *B*, later stage; *C*, common carotid; *Ce*, *Ci*, external and internal carotid. For explanation of other letters, see text. (*Tandler*.)

Branches.—(*a*) A **prevertebral branch** which supplies the prevertebral muscles of the neck and anastomoses with the ascending cervical branch of the inferior thyroid artery.

(*b*) **Pharyngeal branches** (**rami pharyngei**), two or three in number, which supply the constrictor muscles and the mucous membrane of the pharynx.

(*c*) **Meningeal Branches.**—A number of small twigs, into which the artery breaks up as it approaches the base of the skull, pass through the jugular and anterior condyloid foramina to supply the dura mater of the posterior fossa of the skull, and through the cartilage of the middle lacerated foramen to supply the dura of the middle fossa.

Variations.—The ascending pharyngeal frequently gives origin to the ascending palatine and more rarely to the superior laryngeal artery. It is very variable in its origin, not infrequently being given off from one or other of the neighboring branches of the external carotid.

6. **The Sterno-Mastoid Artery.**—The sterno-mastoid artery (**a. sterno-cleidomastoidea**) arises from the posterior surface of the external carotid, near its origin, and passes downward and backward to enter the sterno-cleido-mastoid muscle along with the spinal accessory nerve. It is a comparatively small vessel and is not infrequently absent, being replaced by branches passing to the muscle from other arteries. When it is present, the hypoglossal nerve bends around to it to pass forward to the lingual muscles.

7. **The Occipital Artery.**—The occipital artery (**a. occipitalis**) (Figs. 691, 692) arises from the posterior surface of the carotid, opposite or a little below the facial. It passes upward and backward, and is at first partly covered by the posterior belly of the digastric and the stylo-hyoid muscles, the parotid gland, and the temporo-maxillary vein. It crosses in succession, from before backward, the hypoglossal nerve, which, when the sterno-mastoid artery is wanting, winds around it to pass forward to the tongue, the pneumogastric nerve, the internal jugular vein, and the spinal accessory nerve. It then passes more deeply, lying in a groove on the posterior surface of the mastoid process and beneath the origin of the posterior belly of the digastric, the sterno-cleido-mastoid, and the splenius capitis. Emerging from beneath these muscles, it reappears in the upper part of the occipital triangle, and then ascends in a tortuous course over the back of the skull, sometimes perforating the trapezius near its origin, and breaks up into numerous branches which anastomose with branches from the artery of the opposite side and with those of the posterior auricular and superficial temporal. In this last part of its course it is superficial, lying beneath

the integument upon the aponeurosis of the occipito-frontalis. The artery pierces the deeper structures, accompanied by the great occipital nerve, a short distance lateral to and a little below the external occipital protuberance.

Branches.—In addition to its terminal branches, the occipital artery gives off :

(*a*) A **superior sterno-mastoid branch** which supplies the upper part of the sterno-cleido-mastoid.

(*b*) **Posterior meningeal branches**, one or more slender vessels which pass upward along the internal jugular vein and, entering the skull by the jugular foramen, are supplied to the dura mater of the posterior fossa.

(*c*) An **auricular branch** (**ramus auricularis**) which passes upward over the mastoid process to supply the pinna of the ear.

(*d*) A **mastoid branch** (**ramus mastoideus**) which enters the skull by the mastoid foramen and supplies the mucous membrane lining the mastoid cells, the diploë, and the dura mater.

(*e*) An **arteria princeps cervicis** (**ramus descendens**) which arises from the artery, just as it passes out from beneath the splenius and descends the neck, supplying the adjacent muscles and anastomosing with the superficial cervical branch of the transversalis colli and with the profunda cervicis from the superior intercostal.

(*f*) **Muscular branches** (**rami musculares**) which are given off all along the course of the artery to the neighboring muscles.

Anastomoses.—The occipital artery makes comparatively large and abundant anastomoses in the scalp with the stylo-mastoid and temporal arteries, and also, by means of its art. princeps cervicis, with branches of the transversalis colli and superior profunda arteries, which arise from the subclavian. These latter anastomoses are of considerable importance in the development of a collateral circulation after ligation of either the common carotid or the subclavian arteries.

Variations.—The occipital artery occasionally passes superficial to the sterno-cleido-mastoid muscle instead of beneath it, and it not infrequently gives origin to the ascending pharyngeal artery or to the stylo-mastoid.

Practical Considerations.—The occipital artery is rarely formally ligated. The *cervical portion* may be reached through an incision along the anterior border of the sterno-mastoid, beginning midway between the ramus of the mandible and the lobe of the ear and extending downward two and a half inches. The deep fascia at the upper angle of the wound (parotid fascia) is spared on account of the risk of salivary fistula. At the lower angle it is divided, the parotid and sterno-mastoid are separated, and the digastric and stylo-hyoid muscles recognized and drawn upward. The occipital artery, near its origin, will then be seen crossing the internal carotid artery and internal jugular vein and in contact with the curve of the hypoglossal nerve where it turns to cross the neck. The artery may be ligated close behind the nerve, the needle being passed from without inward to avoid the jugular vein. The *occipital portion* is approached through an almost horizontal incision two inches in length, beginning at the tip of the mastoid apophysis and extending backward and a little upward. The outer fibres of the sterno-mastoid and its aponeurotic expansion, the splenius, and often the complexus, must then be divided and the pulsation of the artery sought for in the space between the mastoid and the transverse process of the atlas, whence the vessel may be traced outward. If it is isolated near to the mastoid, great care must be taken not to injure the important mastoid venous tributaries of the occipital vein which in this region connect it with the lateral sinus.

8. **The Posterior Auricular Artery.**—The posterior auricular artery (**a. auricularis posterior**) (Fig. 693) arises from the external carotid after it has passed beneath the posterior belly of the digastric. It passes upward and backward, covered at first by the parotid gland, which it supplies, and divides in the angle between the pinna and the mastoid process into terminal branches, some of which supply the pinna, while others anastomose with branches from the occipital and superficial temporal.

Branches.—In addition to branches to the parotid gland and to neighboring muscles, it gives rise to the **stylo-mastoid artery** (**a. stylomastoidea**). This vessel enters the stylo-mastoid foramen and traverses the facial canal (aqueduct of Fallopius) as far as the point at which the hiatus Fallopii passes off from it. During its course through the canal it gives off branches to the mucous membrane lining the mastoid cells, to the stapedius muscle, and to the mucous membrane of the middle ear, those twigs which pass to the inner surface of the tympanic membrane anastomosing with the tympanic branch of the internal maxillary. Arrived at the hiatus Fallopii, the artery accompanies the great superficial petrosal nerve through that canal and enters the cranium, supplying the dura mater and anastomosing with branches of the middle meningeal artery.

Variations.—The stylo-mastoid artery may arise from the occipital or its place may be taken by the petrosal branch of the middle meningeal, with which the stylo-mastoid normally anastomoses.

9. **The Superficial Temporal Artery.**—The superficial temporal artery (**a. temporalis superficialis**) (Fig. 693) is the continuation of the external carotid after it has given off the internal maxillary. At its origin it is embedded in the substance of the parotid gland, and is directed upward over the root of the zygoma and immediately in front of the pinna. After ascending a short distance, usually about 2 cm., upon the aponeurosis covering the temporal muscle, it divides into an anterior and a posterior branch, which, diverging and branching repeatedly, pass upward over the temporal and occipito-frontal aponeuroses almost to the vertex of the skull, anastomosing with the supra-orbital branches of the ophthalmic branch of the internal carotid, with the posterior auricular and occipital branches of the external carotid, and with the artery of the opposite side.

Branches.—

(*a*) **Parotid branches** (**rami parotidei**), small branches to the parotid gland.

(*b*) **Articular branches** to the temporo-mandibular articulation.

(*c*) **Muscular branches** to the masseter muscle.

(*d*) The **anterior auricular branches** (**rami auriculares anteriores**) supply the outer surface of the pinna and the outer portion of the external auditory meatus.

(*e*) The **transverse facial artery** (**a. transversa faciei**) arises just below the main stem of the artery, crosses the zygoma, and is directed forward parallel with the zygoma and between it and the parotid duct. It gives off branches to neighboring muscles and to the integument of the cheek, and anastomoses with the masseteric branches of the facial and with the buccal, alveolar, and infra-orbital branches of the internal maxillary.

(*f*) The **middle deep temporal** (**a. temporalis media**) arises just above the zygoma, and after perforating the temporal aponeurosis and muscle, it ascends upon the surface of the skull to anastomose with the deep temporal branches of the internal maxillary artery.

(*g*) The **orbital branch** (**a. zygomaticoorbitalis**) runs forward along the upper border of the zygoma, supplying the orbicularis palpebrarum and also sending branches into the cavity of the orbit.

Anastomoses.—The superficial temporal artery makes extensive anastomoses in the scalp with its fellow of the opposite side, with the occipital and posterior auricular branches of the external carotid, and with the supra-orbital branch of the ophthalmic. By means of the transverse facial it makes anastomoses with the facial and internal maxillary arteries.

Variations.—The principal variations of the superficial temporal are its division into the terminal branches below the level of the zygomatic arch and the absence of its posterior terminal branch; in the latter case the area of distribution of the posterior branch is supplied by the posterior auricular or the occipital artery.

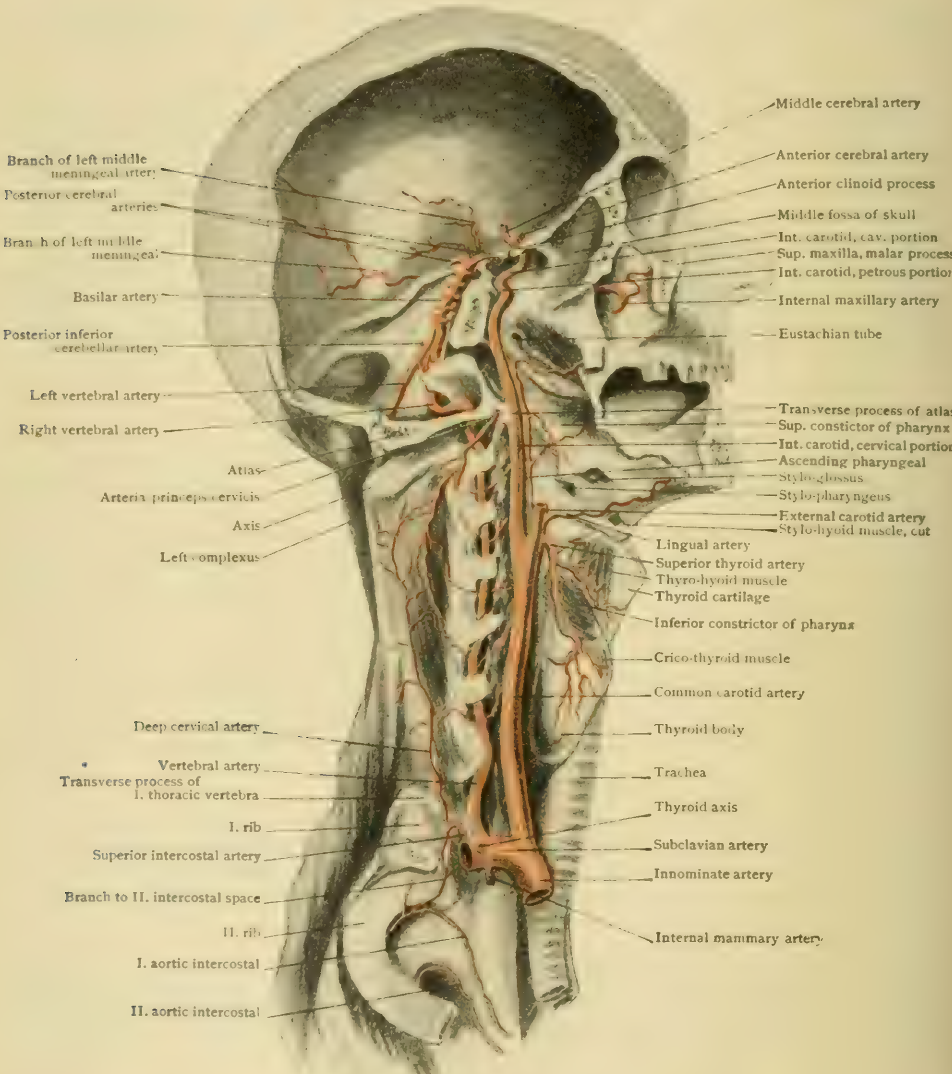
Practical Considerations.—The superficial temporal artery may require ligation on account of wound of the vessel, or of one of its branches, or in cases of aneurism. It or one of its chief subdivisions used frequently to be selected for the now rare operation of arteriotomy. The vessel never becomes very superficial immediately after emerging from beneath the upper part of the parotid. In the first portion of its track of ascent its pulsations are difficult to perceive. In the presence of the least swelling of the region they become incapable of serving as a guide for the incision (Farabeuf).

Ligation.—The skin, superficial fascia, and some fibres of the attrahens aurem muscle are divided for an inch on a vertical line between the tragus and the condyle of the mandible, a little nearer the latter. The artery will be found closely bound by connective-tissue bands to the temporal aponeurosis.

THE INTERNAL CAROTID ARTERY.

The internal carotid (Figs. 693, 695) is the second terminal branch of the common carotid, from which it arises on a level with the upper border of the thyroid

Fig. 695.



Deep dissection, showing internal carotid, vertebral and superior intercostal arteries.

cartilage. In the *first* or *cervical portion* of its course it lies upon the outer side of the external carotid, but, as it passes upward, it comes to lie behind and then internal to that vessel, from which it is separated by the stylo-hyoid, digastric, and stylopharyngeus muscles. It passes almost vertically up the neck to the entrance to the carotid canal, resting posteriorly on the prevertebral fascia covering the rectus capitis

anticus major, and having upon its median side the wall of the pharynx and laterally the internal jugular vein, between which and the artery, and on a plane slightly posterior to both, is the pneumogastric nerve. It is also in relation in the upper part of this cervical portion of its course with the glosso-pharyngeal nerve, which lies at first behind it, but crosses its external surface lower down as it bends forward towards the tongue, and with the superior sympathetic ganglion, whose cardiac branch descends along its internal surface, while the pharyngeal branches cross it and the carotid branch ascends with the artery to the carotid canal, in which it breaks up to form the carotid plexus.

In the *second* or *petrosal portion* of its course the internal carotid traverses the carotid canal, to whose direction it conforms, passing at first vertically upward and then bending so as to run forward and inward to enter the cranial cavity at the foramen lacerum medium.

It then enters upon the *third* or *intracranial portion* of its course, ascending at first towards the posterior clinoid process, but soon bending forward and entering the outer wall of the cavernous sinus. In this it passes forward, accompanied by the sixth nerve (abducens), and at the level of the anterior clinoid process bends upward, pierces the dura mater, and quickly divides into its terminal branches.

Branches.—Throughout its cervical portion the internal carotid normally gives off no branches; in its petrosal portion, in addition to some small twigs to the periosteum lining the carotid canal, it gives origin to (1) a *tympanic branch.* In its intracranial portion, in addition to small branches to the walls of the cavernous sinus and the related cranial nerves, to the Gasserian ganglion, and to the pituitary body, there arise (2) *anterior meningeal branches*, (3) the *ophthalmic*, (4) *posterior communicating*, (5) *anterior choroid arteries.* And, finally, its terminal branches, (6) the *middle* and (7) the *anterior cerebral arteries.*

Variations.—In its cervical portion the internal carotid occasionally takes a somewhat sinuous course, and, especially in its upper part, may be thrown into a pronounced horseshoe-shaped curve. It may give rise to branches which normally spring from the external carotid, as, for example, the ascending pharyngeal and the lingual, and accessory branches may arise from its intracranial portion.

Practical Considerations.—The internal carotid artery, on account of its deeper position, is not so often wounded as the external carotid. It has been punctured through the pharynx and has been wounded in tonsillotomy (page 1608).

Aneurism of the internal carotid is not common. When it involves the *petrosal* or *intracranial portion* of the vessel it causes symptoms referrible to those regions and better dealt with after the venous system has been described (page 873). In its cervical portion it shows a tendency to become tortuous in elderly persons, owing doubtless to its fixity above, where it enters the carotid canal, and to the relative lack of fixation below (Taylor).

As the artery is crossed externally by the dense layers of the deep cervical fascia, and by the stylo-hyoid, stylo-glossus, stylo-pharyngeus, and digastric muscles, the progress of a swelling in this direction is strongly resisted. Internally the middle constrictor and mucous membrane of the pharynx offer far less obstruction to the extension of the aneurism, and in many of the recorded cases a pulsating pharyngeal protrusion has been the chief symptom. The effects of pressure on surrounding structures, the internal jugular vein, and the pneumogastric and sympathetic nerves, for example, are not unlike those observed in other carotid aneurisms. The direct interference with cerebral circulation is greater in aneurism of the internal carotid, and vertigo, headache, drowsiness, etc., are apt to be more conspicuous as early symptoms.

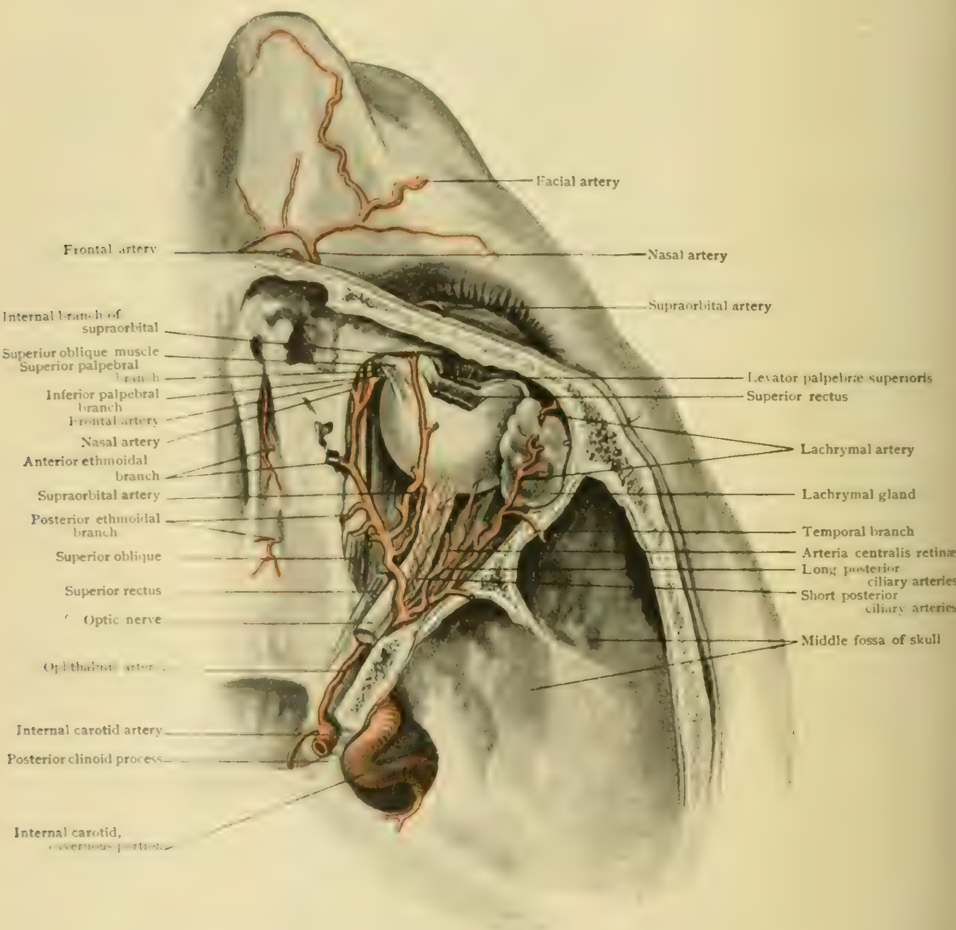
Ligation.—The vessel may be reached close to its origin and tied through the same incision as that used in ligating the external carotid (page 733). The sterno-mastoid muscle is drawn outward, the digastric muscle and hypoglossal nerve (which are usually seen) upward, and the external carotid artery inward. The two vessels should be carefully distinguished. The needle should be passed from with-

out inward, avoiding the internal jugular vein, the pneumogastric and sympathetic nerves, and the ascending pharyngeal and external carotid arteries.

The collateral circulation is carried on through the vertebrals and the vessels of the circle of Willis and is freely re-established.

1. **The Tympanic Artery.**—The tympanic artery (**ramus caroticotympanicus**) is a small vessel which arises from the petrosal portion of the internal carotid. It passes through a foramen in the wall of the carotid canal to supply the mucous membrane of the middle ear, anastomosing with the tympanic branches of the stylomastoid and internal maxillary arteries.

FIG. 696.



Branches of right ophthalmic artery, seen from above after removal of roof of orbit.

2. **The Anterior Meningeal Arteries.**—The anterior meningeal arteries are a number of small branches which arise from the intracranial portion of the internal carotid and are supplied to the neighboring dura mater, anastomosing with the branches of the anterior ramus of the middle meningeal artery.

3. **The Ophthalmic Artery.**—The ophthalmic artery (**a. ophthalmica**) (Figs. 696, 697) arises from the internal carotid immediately after it has issued from the roof of the cavernous sinus. It passes forward beneath the optic nerve and traverses the optic foramen with that structure. In the orbit it ascends to the outer side of the optic nerve and, crossing over it, passes in a sinuous course towards the inner wall

of the orbit, along which it runs between the superior oblique and internal rectus muscles to the inner angle, where it terminates by dividing into *palpebral*, *frontal*, and *nasal* branches.

Branches.—(*a*) The **arteria centralis retinæ** arises from the ophthalmic while that vessel is still below the optic nerve. It runs forward along the under surface of the nerve to a point about 15 mm. from the posterior surface of the eye, where it passes into the substance of the nerve and continues its course forward in the centre of that structure. Arrived at the retina, the artery divides into two main branches, one ascending and the other descending, and these, branching repeatedly, form an arterial net-work upon the surface of the retina. The finer branches of the net-work extend deeply into the substance of the retina, although none reach the layer of visual cells. They pass over directly into the corresponding veins without making connections with any of the other arteries supplied to the eyeball. Just after its entrance into the eyeball, however, the main stem of the artery anastomoses with the short ciliary vessels.

(*b*) The **ciliary arteries**, which are distributed to the choroid coat, the ciliary processes, and the iris, are somewhat variable in their number and origin. Two sets are distinguishable, and are named from their relative position the posterior and anterior ciliary arteries.

(*aa*) The *posterior ciliary arteries* (**aa. ciliares posteriores**) arise from the ophthalmic artery as it crosses over the optic nerve, either as two trunks which pass forward, the one on the inner and the other on the outer side of the optic nerve, or else as a variable number of small vessels. Eventually the vessels break up into from ten to twenty branches, which surround the distal portion of the optic nerve, and, piercing the sclerotic, are distributed to the choroid coat of the eye. Two of the vessels, lying one on either side of the optic nerve, are usually stronger than the others, pierce the sclerotic some distance nearer the equator of the eyeball, and are termed the *long posterior ciliary arteries* (**aa. ciliares posteriores longae**). They pass forward between the sclerotic and choroid coats, send branches to the ciliary muscle, and divide at the peripheral border of the iris into two stems, which, passing around the iris, unite with their fellows of the opposite side and with branches of the anterior ciliary arteries to form the *circulus arteriosus iridis*, from which branches radiate to the iris and the ciliary processes.

(*bb*) The *anterior ciliary arteries* (**aa. ciliares anteriores**) usually take their origin from the muscular branches of the ophthalmic and accompany the tendons of the recti muscles (two arteries being associated with each muscle, except in the case of the external rectus, where there is only one) to the sclerotic, where they send off perforating branches which, after piercing the sclerotic, unite with the long ciliaries to form the arterial circle of the iris. The main stems are continued onward towards the margin of the cornea, where they divide and anastomose to form a narrow net-work surrounding that portion of the eyeball and also give branches to the conjunctiva. An anterior ciliary vessel is frequently contributed by the lachrymal artery.

(*c*) The **lachrymal artery** (**a lacrimalis**) arises from the ophthalmic as it passes upward over the external surface of the optic nerve and passes forward and outward, in company with the lachrymal nerve, along the upper border of the external rectus muscle. It traverses the substance of the lachrymal gland, to which it gives branches, and terminates in small branches to the eyelids. In its course it gives off a number of small twigs to the external rectus muscle; a *meningeal branch*, which passes back into the cranium through the sphenoidal fissure and anastomoses with the middle meningeal; and a *malar branch*, which passes to the temporal fossa through a small canal in the malar bone and anastomoses with the anterior deep temporal and the transverse facial arteries.

(*d*) The **muscular branches** (**rami musculares**) are somewhat irregular in their number and origin. Usually there are two principal stems and a variable number of small twigs, but occasionally the two principal stems arise by a common trunk. When the two are distinct, the *inferior* one arises close to the lachrymal, and is distributed to the inferior and internal recti and the inferior oblique muscles; while the *superior*, smaller and less constant, arises after the ophthalmic has crossed over the optic nerve, and is distributed to the superior and external muscles of the orbit. In addition to branches to the muscles, these arteries also give origin to the anterior ciliary arteries described above.

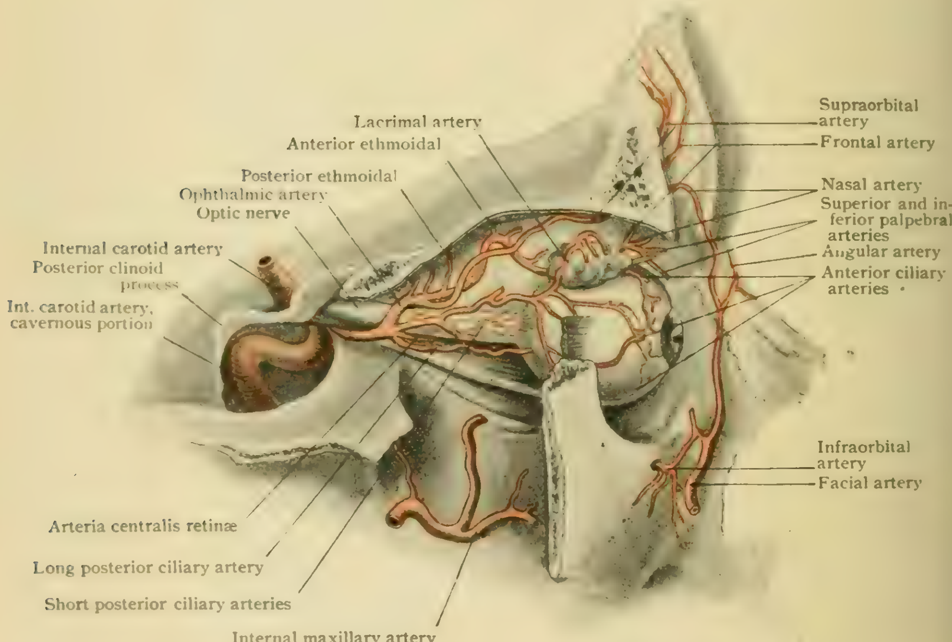
(*e*) The **supraorbital artery** (**a. supraorbitalis**) arises as the ophthalmic passes over the optic nerve. It is at first directed upward, and then passes forward between the periosteum of the roof of the orbit and the levator palpebræ superioris, and, making its exit from the orbit through the supraorbital notch or foramen, terminates in branches which ascend over the frontal bone towards the vertex of the skull, supplying the integument and periosteum and anastomosing with the superficial temporal artery. In its course through the orbit it gives off periosteal, diploic, and muscular twigs, and, after its exit from the supraorbital notch, a palpebral branch to the upper eyelid.

(*f*) The **ethmoidal arteries** are two in number, and arise from the ophthalmic as it passes along the inner wall of the orbit. The **posterior ethmoidal** (**a. ethmoidalis posterior**), which is the

smaller and less constant of the two, passes through the posterior ethmoidal foramen and is distributed to the mucous membrane lining the posterior ethmoidal cells and the upper posterior part of the nasal septum, where it anastomoses with the spheno-palatine branch of the internal maxillary. It sometimes arises from the supraorbital artery. The **anterior ethmoidal** (**a. ethmoidalis anterior**) passes through the anterior ethmoidal foramen along with the nasal nerve, and, entering the cranium, passes forward over the cribriform plate of the ethmoid to the nasal slit at the side of the crista galli. Through this slit it enters the nasal cavity and passes downward in a groove upon the under surface of the nasal bone, supplying the nasal mucous membrane. While within the cranium it gives off a small meningeal branch to the dura mater of the anterior portion of the cranium, and it also sends branches to the mucous membrane lining the anterior and middle ethmoidal cells and the frontal sinuses.

(*g*) The **palpebral branches** (**aa. palpebrales mediales**) are two in number, and are distributed to the upper and lower eyelids respectively. They arise opposite the pulley of the superior oblique muscle and descend towards the inner canthus of the eye. Each artery then bends outward towards the outer canthus along the free border of the lid, between the tarsal cartilage and the orbicularis muscle, forming the palpebral arches (*arcus tarseus superior et inferior*),

FIG. 697.



Branches of ophthalmic artery, seen from side after removal of lateral orbital wall.

from which branches pass upward or downward, as the case may be, to supply the orbicularis, the Meibomian glands, and the integument of the lid. As they approach the outer canthus, the arches anastomose with the palpebral branches of the lachrymal artery.

(*h*) The **frontal branch** (**a. frontalis**) is usually small, and is distributed to the integument over the glabella and to the pyramidalis nasi and frontalis muscles. It also sends some twigs to the eyelids.

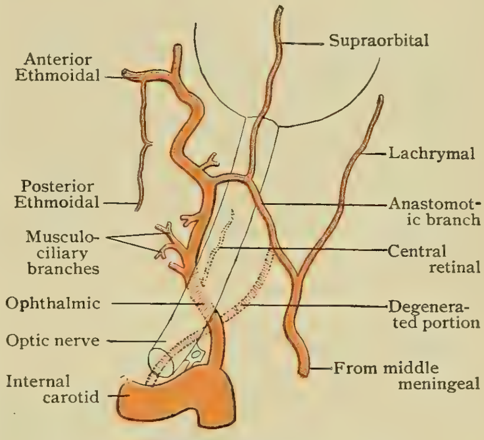
(*i*) The **nasal artery** (**a. dorsalis nasi**) is the true terminal branch of the ophthalmic. It passes downward in the angle formed by the nose and the lower eyelid and becomes directly continuous with the angular portion of the facial artery. In its course it gives branches to the walls of the lachrymal sac and to the integument of the root of the nose.

Anastomoses.—The principal communications of the ophthalmic artery are with the superficial temporal, internal maxillary, and facial branches of the external carotid. With the first of these it communicates extensively by means of the supraorbital branch and less importantly through the anastomosis of the malar branch of the lachrymal with the transverse facial artery. It makes a very important anasto-

mosis with the middle meningeal branch of the internal maxillary through the lachrymal branch, and communicates also with the spheno-palatine artery by means of the ethmoidal branches. The anastomosis of the nasal branch with the angular artery from the facial is also a large one, the two vessels being practically continuous.

Variations.—In addition to the variations in the number and origins of its branches, the ophthalmic artery also presents variations in its course, in that, instead of passing to the inner wall of the orbit above the optic nerve, it sometimes passes below that structure. The most striking variation which it presents, however, is associated with the development of the branch of the lachrymal artery, which passes back through the sphenoidal fissure to anastomose with the middle meningeal (Fig. 698). Occasionally this branch becomes exceptionally large and forms the main stem of the lachrymal artery, the connection of that vessel with the ophthalmic vanishing, so that it seems to be a branch of the middle meningeal. A further step in this process which sometimes occurs results in the origin of the entire ophthalmic system of vessels from the middle meningeal artery.

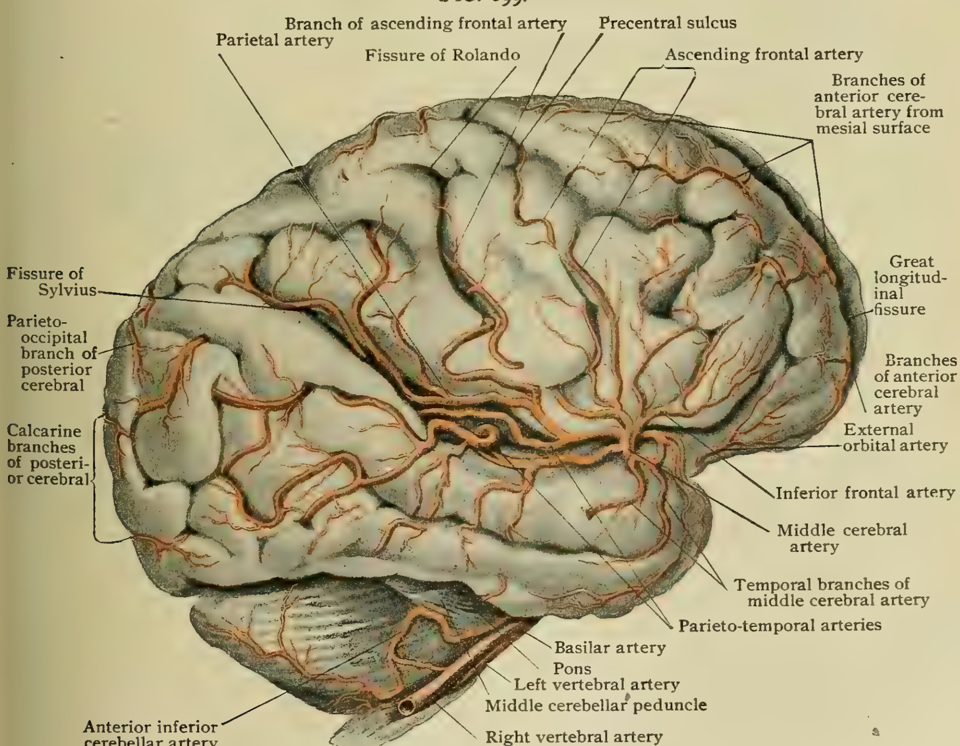
FIG. 698.



Variations of ophthalmic artery; lachrymal coming chiefly from middle meningeal. (*Meyer.*)

4. **The Posterior Communicating Artery.**—The posterior communicating artery (**a. communicans posterior**) (Fig. 702) arises from the posterior surface of the

FIG. 699.



Lateral surface of brain, showing cortical branches of middle cerebral artery; those of anterior and posterior cerebral arteries are seen curving over supero-mesial border of cerebral hemisphere.

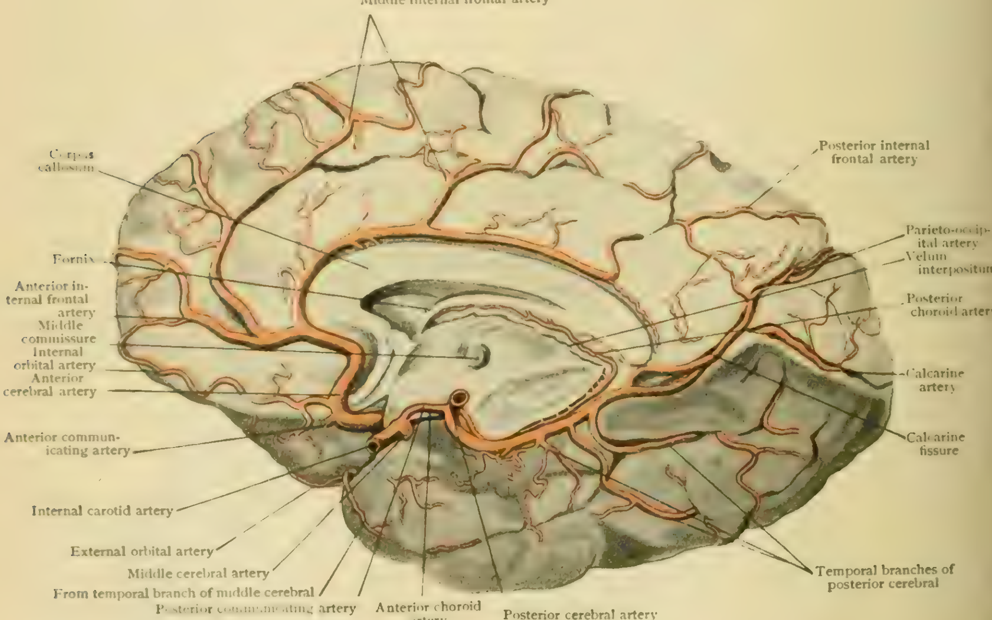
internal carotid, opposite the sella turcica. It is directed backward beneath the optic tract and the inner border of the crus cerebri, and terminates posteriorly by

opening directly into the posterior cerebral artery. In its course it gives off twigs to the tuber cinereum, the corpora albicantia, and the crus cerebri.

5. **The Anterior Choroid Artery.**—The anterior choroid artery (**a. choroidea**) (Fig. 702) arises from the posterior surface of the internal carotid, slightly distal to the posterior communicating artery. It is directed outward and backward at first, and then, curving upward between the brain-stem and the temporal lobe, it gives branches to the hippocampus major. It is then continued upward and forward as the artery of the choroid plexus of the lateral ventricle, and anastomoses at the foramen of Monro with the artery of the choroid plexus of the third ventricle, which comes from the superior cerebellar branch of the basilar artery.

6. **The Middle Cerebral Artery.**—The middle cerebral artery (**a. cerebri media**) (Figs. 699, 702) is one of the terminal branches of the internal carotid. It passes at first outward to the lower end of the Sylvian fissure, and is then directed backward and upward, lying at first deeply in the fissure close to the surface of the

FIG. 700.



Mesial surface of cerebral hemisphere, showing cortical branches of anterior and posterior cerebral arteries.

island of Reil, but gradually becoming more superficial until at the posterior extremity of the horizontal limb of the fissure it reaches the surface and divides into branches which ramify over the lateral surface of the cerebral hemisphere.

Branches.—In its course outward to enter the Sylvian fissure it gives off a number of small **central branches** which penetrate the substance of the cerebral hemisphere at the anterior perforated space, and, as the striate arteries, supply the corpus striatum. These *antero-lateral ganglionic* branches, as they are often called, are arranged as two groups: (*a*) the **internal striate arteries**, which pass upward through the lenticular nucleus (globus pallidus) and the internal capsule and end in the caudate nucleus, supplying the anterior part of the structures traversed; (*b*) the **external striate arteries**, which after traversing the putamen and the internal capsule terminate in either the caudate nucleus or the optic thalamus. One of the former (*lenticulo-striate*) vessels, which passes around the outer border of the lenticular nucleus before traversing its substance, is larger than the others and, since it frequently ruptures, is known as the *artery of cerebral hemorrhage*. While in the Sylvian fissure the middle cerebral artery gives off numerous branches to the cortex of the island of Reil and continues into the **cortical branches**, which are distributed to the lateral surface of the hemisphere and are usually four in

number. (*a*) The **inferior frontal** is distributed to the inferior frontal convolutions, (*b*) the **ascending frontal** passes to the lower portion of the ascending frontal convolution, (*c*) the **parietal** supplies the whole of the ascending parietal convolution and the neighboring portions of the inferior parietal, and (*d*) the **parieto-temporal** passes to all the convolutions around the posterior limb of the fissure of Sylvius.

7. **The Anterior Cerebral Artery.**—The anterior cerebral artery (a. cerebri anterior) (Fig. 700) is the smaller of the terminal branches of the internal carotid. It passes forward above the optic chiasma to the anterior end of the great longitudinal fissure, and, bending upward around the rostrum of the corpus callosum, is continued backward along the medial surface of the cerebral hemisphere to the posterior portion of the parietal lobe. At its entrance into the great longitudinal fissure it is connected with its fellow of the opposite side by a short transverse vessel termed the **anterior communicating artery** (Fig. 702).

Branches.—Immediately after it has crossed the optic chiasma the anterior cerebral artery gives off a number of small **central branches** (*antero-mesial ganglionic*), which penetrate the base of the brain and are distributed to the lamina cinerea, the rostrum of the corpus callosum, the septum lucidum, and the tip of the caudate nucleus. Throughout its course in the great longitudinal fissure it gives branches to the corpus callosum and also **cortical branches** to the medial and lateral surfaces of the cerebral hemisphere. These branches are (*a*) the **orbital**, which vary in number and are distributed to the orbital surface of the frontal lobe, also supplying the olfactory bulb; (*b*) the **anterior internal frontal**, which supplies the anterior and lower part of the marginal convolution and sends branches to the lateral surface of the hemisphere supplying the superior and middle frontal convolutions; (*c*) the **middle internal frontal**, which is distributed to the middle and posterior parts of the marginal convolution and to the adjacent portions of the superior and ascending frontal and ascending parietal convolutions; and (*d*) the **posterior internal frontal** or **quadrate**, which, in addition to sending branches to the corpus callosum, supplies the quadrate lobe and the upper part of the superior parietal convolution. These branches anastomose upon the inferior and lateral surfaces of the hemisphere with the branches of the middle cerebral artery, the main stem of the artery anastomosing posteriorly with branches of the posterior cerebral.

Anastomoses of the Carotid System.—Although the majority of the anastomoses of the branches of the carotid arteries are with one another, yet there is a sufficient amount of communication with other vessels to allow of the establishment of a collateral circulation after ligation of the common carotid of one side. The connections which are available for the circulation in such a case are as follows. (1) There is abundant communication between the branches of the right and left external carotids across the median line; (2) the anterior communicating artery forms an important communication between the internal carotids of opposite sides; (3) anastomoses exist between the ascending cervical branch of the inferior thyroid, the superficial cervical branch of the transversalis colli, and the deep cervical branch of the superior intercostal, on the one hand, all of these being branches of the subclavian artery, and the a. princeps cervicis, a branch of the occipital artery; (4) abundant communications exist between the terminal branches of the inferior thyroid from the subclavian and the superior thyroid from the external carotid; and, finally, (5) by means of the posterior communicating artery the internal carotid may receive blood from the posterior cerebral artery, which, through the basilar and vertebral arteries, belongs to the subclavian system.

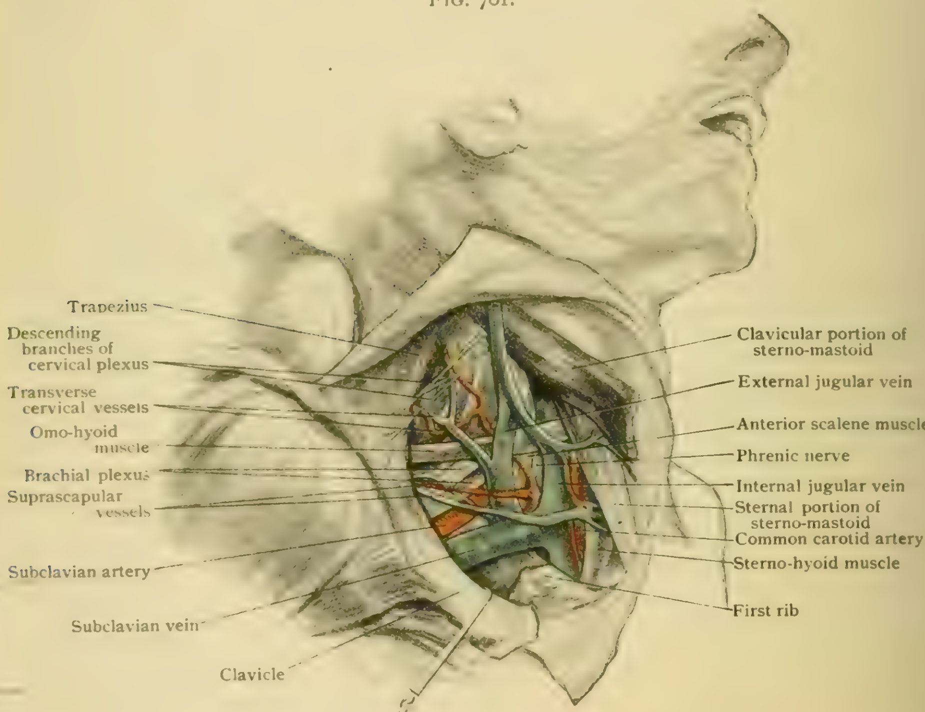
THE SUBCLAVIAN ARTERY.

In the primary arrangement of the branchial blood-vessels, while there are two aortic arches (Fig. 678), the two subclavian arteries arise symmetrically from these arches as lateral segmental branches corresponding to the seventh cervical segment. With the disappearance of the lower portion of the right arch, however, an apparent lack of symmetry in their origin supervenes, the vessel of the right side arising from the innominate stem, while that of the left side springs directly from the persisting aortic arch. As a matter of fact, however, the proximal portion of the right aortic arch is represented by the innominate stem, together with a small portion of the proximal end of the right subclavian artery, so that the original morphological sym-

metry is retained ; but, since a portion of the original right aortic arch is included in the adult right subclavian, this vessel is a little more than equivalent to its fellow of the opposite side. Furthermore, since the innominate stem ascends directly upward from its origin, a topographical asymmetry of the two vessels results.

The origin of the *right subclavian* is opposite the right sterno-clavicular articulation, and from that point the artery ascends upward and outward in a gentle curve over the dome of the pleura to the inner border of the scalenus anticus. The origin of the *left subclavian* is from the termination of the transverse portion of the aortic arch, and is consequently much deeper in the thorax (Fig. 690). From its origin it ascends at first almost vertically and then curves outward and slightly forward to reach the inner border of the scalenus anticus. From this point onward the course of the two arteries is the same. Passing behind the anterior scalene muscle, each artery continues its course outward across the root of the neck, curving downward to the outer border of the first rib, at which point it becomes known as the axillary artery.

FIG. 701.



Dissection of neck, showing relations of blood-vessels and nerves; clavicle disarticulated from sternum and drawn down.

In consequence of the difference in origin, the right subclavian artery is usually approximately 7.5 cm. (3 in.) in length, or about one inch shorter than the left. In its course across the root of the neck the height which the subclavian artery may reach varies considerably in different individuals ; in some it never rises above the clavicle, while in others its highest point may be from 2.5–3 cm. (1–1½ in.) above that bone. Most frequently it reaches a point about 1.5 cm. (⅝ in.) above the clavicle, this highest point being reached as it passes beneath the scalenus muscle. As it commences its downward course towards the first rib, the artery undergoes a more or less pronounced diminution in diameter, which persists for a distance of from 0.5–1 cm., and is followed by an enlargement to about its original size, what has been termed an arterial isthmus and spindle thus resulting (page 720).

Relations.—For convenience in description, the subclavian artery is usually regarded as consisting of three portions. The first portion extends from its origin to the inner edge of the scalenus anticus, the second portion lies behind that muscle,

while the third portion extends from the outer border of the scalenus to the conventional termination of the artery at the lower border of the first rib. On account of the difference in their origins, the relations of the first portions of the right and left vessels differ somewhat.

The **first portion of the right subclavian artery** lies behind the clavicular portion of the sterno-cleido-mastoid, and is crossed *in front* by the internal jugular and vertebral veins and by the right pneumogastric, phrenic, and superior sympathetic cardiac nerves. *Behind*, it is in relation with the transverse process of the seventh cervical vertebra, with the inferior cervical sympathetic ganglion, and with the right recurrent laryngeal nerve, which winds around its under surface from in front. *Below*, it is in contact with the dome of the right pleura.

The **first portion of the left subclavian artery,** at its origin, is deeply seated in the thoracic cavity and ascends almost vertically through the superior mediastinum. *Behind*, and somewhat medial to it, are the œsophagus, the thoracic duct, and the longus colli muscle, and at its emergence from the thorax the lower cervical sympathetic ganglion. *Medial*, or internal to it, are the trachea and the left recurrent laryngeal nerve, and *lateral* to it, on its left side, are the left pleura and lung, which also overlap it in front. Near its origin it is *crossed* by the left innominate (brachio-cephalic) vein, and, shortly before it passes over into the second portion, it is crossed by the internal jugular, vertebral, and subclavian veins, as well as by the phrenic nerve and the thoracic duct, the latter arching over it to reach its termination in the subclavian vein. The left pneumogastric and cardiac sympathetic nerves descend into the thorax in front of it, the pneumogastric, before passing over the aortic arch, coming into contact with the anterior surface of the vessel. As it emerges from the thorax the subclavian lies behind the clavicular portion of the sterno-cleido-mastoid. In the neck it rests below upon the dome of the left pleura.

The **second portion of the subclavian artery,** the relations of which and of the succeeding portion of the vessel are the same on both sides, *in front* is covered by the scalenus anticus muscle, anterior to which and on a slightly lower plane is the subclavian vein. *Behind* and above it are the trunks of the brachial plexus, which separate it from the scalenus medius, and *below* it is in contact with the pleura.

The **third portion of the subclavian artery** lies in the supraclavicular fossa, and is covered only by the skin, the platysma, and that part of the deep cervical fascia which contains the external jugular vein and the supraclavicular branches of the cervical plexus, and encloses a quantity of fatty tissue, in which the suprascapular artery passes outward. *Behind*, it is in contact with the scalenus medius and the brachial plexus, and *above* it are the brachial plexus and the posterior belly of the omo-hyoid. *Below*, it rests upon the first rib, at the lower border of which the vessel becomes the axillary artery.

Branches.—Considerable variation exists in the arrangement of the branches of the subclavian, but in what is probably the most frequent arrangement the branches are as follows :

From the first portion arise (1) the *vertebral*, (2) the *internal mammary*, (3) the *superior intercostal*, and (4) the *thyroid axis* ; from the second portion no branches are given off ; from the third portion (5) the *transverse cervical.*

Variations.—The variations in the origin of the subclavian artery have already been considered in describing the variations of the aortic arch (page 725). Other anomalies occur in its relation to the scalenus anticus, in front of which it sometimes passes, and it may also traverse the substance of the muscle obliquely. More rarely the artery divides at the inner border of the muscle, the two branches so formed continuing onward through the axilla and down the arm to become the radial and ulnar arteries.

Numerous supernumerary branches may arise from the subclavian. These may be either (1) accessory to the branches normally arising from the artery, such as an accessory vertebral, an accessory internal mammary, or an accessory inferior thyroid ; (2) they may be branches, such as the long thoracic, dorsal scapular, subscapular, and the anterior and posterior circumflexes, which normally arise from the artery, but have secondarily shifted to the subclavian as the result of the enlargement of anastomoses which they make with branches of that vessel ; or (3) they may be branches to neighboring organs, such as a bronchial or a pericardial branch, or occasionally the thyroidea ima (page 729).

Practical Considerations.—The subclavian artery may require ligation, on account of stab wounds, as a preliminary to the removal of growths—axillary or scapular—or to an interscapulo-thoracic amputation, or in cases of axillary or subclavian aneurism, or, together with the common carotid artery, in aortic or innominate aneurism.

On the surface of the neck the subclavian artery is represented by a curve, convex upward, beginning at the sterno-clavicular articulation and ending beneath the middle of the clavicle, its highest point being on an average about five-eighths of an inch above that bone. The vein is lower, is in front of the artery (separated from it by the scalenus anticus muscle), and is usually nearly or quite under cover of the clavicle.

Aneurism of the subclavian is more frequent on the right side, probably because of the greater use and consequent greater exposure to strain of the right upper extremity. It may affect any portion of the vessel, but the third portion—external to the scaleni, where it is least supported by surrounding muscles—is most commonly involved either primarily or by extension of an aneurismal dilatation upward from the axillary or downward from the arch of the subclavian. The thoracic portion of the left subclavian is never the primary seat of aneurism.

The *symptoms* are: (*a*) *pain* or *numbness* and *loss of power* in the arm and hand from pressure on the brachial plexus; (*b*) *swelling and œdema* of the arm and hand from pressure on the subclavian vein; (*c*) *hiccough* or *irregular, jerky respiration* from pressure on the phrenic nerve; (*d*) *vertigo, somnolence, defective vision*, from compression of the internal jugular; (*e*) *tumor*, usually appearing in the posterior inferior cervical triangle, with its long diameter approximately parallel with the clavicle, and extending upward and outward; exceptionally it grows downward, but this is rare on account of the resistance offered by the clavicle, the first rib, and the structures filling the costo-clavicular space.

Digital compression of the first and second portions of the artery is practically impossible. The third portion may be imperfectly occluded by making strong pressure directly backward just above the clavicle, a little external to its middle, so that the artery may be flattened out or narrowed against the scalenus medius muscle and the seventh cervical transverse process. Much more effectual pressure may be made at the same point, especially if the tip of the shoulder can be lowered so as to carry the clavicle downward and make the upper surface of the first rib more accessible, in a direction downward, backward, and inward,—*i.e.*, in a line nearly or quite perpendicular to the plane of that surface. The vessel is thus compressed against it, and is not pushed off of it. It will be useful to recall that the outer border of the scalenus anticus and the posterior border of the sterno-mastoid—the latter palpable and often visible—are approximately on the same line, immediately outside of which is the third portion of the vessel. The scalene tubercle—the elevation or roughening on the upper surface of the first rib between the shallow depression for the subclavian vein and the deeper groove for the subclavian artery—gives attachment to the scalenus anticus and, when recognized, serves as a valuable guide to the vessel.

Ligation.—The first portion—between the origin of the vessel and the inner side of the scalenus anticus—has been ligated with uniformly fatal results. On the left side it is so situated as to depth, origin of branches—the vertebral, internal mammary, thyroid axis, and superior intercostal—and contiguity of important structures—the heart, the aorta, the pleura, the innominate vein, the thoracic duct, the pneumogastric, cardiac, recurrent laryngeal and phrenic nerves—that its ligation has only once been accomplished (Rodgers). On the right side the operative procedure is somewhat less difficult, but many of the relations are identical (*vide supra*), and the procedure is still so formidable that its description is included in some works on operative surgery only because the ligation "affords good practice on the dead subject" (Jacobson).

The steps of the operation are the same as those in ligation of the innominate (page 729) until the carotid sheath is reached and opened. The internal jugular vein and pneumogastric nerve should be drawn aside (inward, Agnew; outward, Barwell) and the subclavian recognized, springing from the bifurcation of the innom-

inate at an acute angle with the carotid and deeper by the full diameter of the latter. The needle should be passed from below upward, while the pleura is gently depressed with the finger.

The *second portion*—behind the scalenus anticus—has in a few cases been successfully ligated for aneurism external to it, but the operation does not require special description. It is identical with that for tying the third portion, with the addition of more extensive division of the clavicular portion of the sterno-mastoid and a partial division of the scalenus anticus, having due regard to the position of the phrenic nerve on the inner part of the anterior surface of that muscle.

The *third portion*—from the outer edge of the scalenus anticus to the lower border of the first rib—has been frequently and successfully ligated. Three methods may be described:

1. By the first and usual one it is approached by a transverse incision, parallel with the clavicle and extending along the base of the posterior cervical triangle from the middle of the clavicular head of the sterno-mastoid to the anterior border of the trapezius. This is best made by drawing the skin down and incising it directly upon the bone, in this way easily avoiding the external jugular vein. The platysma muscle and the supraclavicular nerves are divided at the same time. On releasing the skin the wound will be placed about a half-inch above the clavicle. The shoulder is then well depressed so as to lower this bone and increase the supraclavicular space. The deep fascia, which, as it is attached to the superior border of the clavicle, is not pulled down with the skin and platysma, is then divided, the external jugular vein drawn aside or tied and cut, the loose cellular tissue, and possibly the omo-hyoid aponeurosis, scratched through or cut, and one or the other of four landmarks identified: (*a*) the tense outer edge of the anterior scalene muscle or (*b*) the scalene tubercle at the insertion of that muscle into the first rib, the artery lying just outside these on the rib; (*c*) the first rib itself traced inward with the finger from the outer angle of the wound until the artery is reached; (*d*) the lowest cord of the brachial plexus, lying immediately above, or sometimes slightly overlapping the artery. The cord has been mistaken for the vessel, but compression between the finger and the rib does not flatten it out, as in the case of the artery, and, of course, does not arrest the radial pulse. The tubercle is often poorly developed, and has a less close relation to the vessel when the latter rises high above the clavicle. The process of cervical fascia reaching from the posterior border of the scalenus to the sheath of the artery may be so tense as to obscure to both sight and touch the line of the outer edge of the muscle

The artery is cautiously denuded, care being taken to avoid injury to the pleura or to the subclavian vein. The transverse cervical artery is usually above and the suprascapular artery below the line of incision. The phrenic nerve has been known to pass directly over the third portion of the subclavian (Agnew), and the possibility of the presence of this rare anomaly should be remembered. The needle, the tip kept between the artery and the rib, is passed from above downward, and from behind forward and a little inward. In the case of a high arch of the subclavian the third portion is nearly vertical, and it would then be more correct to speak of passing the needle from without inward.

2. The middle of the clavicle for two or more inches, or the whole clavicle, may be resected subperiosteally, as in interscapulo-thoracic amputations, and the approach to the artery greatly facilitated.

3. By strongly elevating—instead of depressing—the shoulder and clavicle, using the arm as a tractor, the artery may be exposed by an incision just *below* and parallel with the middle of the clavicle. A portion of the outer edge of the pectoralis major and some of the inner deltoid fibres will usually have to be divided, although it may be possible to gain sufficient room by drawing the margin of the former muscle inward and that of the latter outward. The cephalic vein dipping in through this intermuscular depression (Mohrenheim's fossa) to join the axillary vein must be avoided. The artery is found lying between the vein internally and the close bundle of the cords of the brachial plexus externally. The point at which the vessel is tied is said to be identical with that at which it is ligated through the usual incision (Dawbarn).

The *collateral circulation* after ligation of the third portion of the subclavian artery is carried on from the proximal or cardiac side of the ligature by (*a*) the suprascapular and posterior scapular; (*b*) the aortic intercostals, the superior intercostals, and the internal mammary; and (*c*) numerous subdivisions of subclavian branches running through the axilla, anastomosing respectively with (*a*) the subscapular, and the acromio-thoracic; (*b*), the subscapular, long thoracic, infrascapular, and dorsalis scapulæ; (*c*) the axillary trunk or its branches.

1. **The Vertebral Artery.**—The vertebral artery (**a. vertebralis**) (Figs. 695, 704), the first and largest branch of the subclavian artery, is destined chiefly for the supply of the spinal cord and the brain, joining with the internal carotid arteries to form the remarkable intracranial anastomotic circle of Willis. In view of its peculiar course, the vertebral artery may be conveniently divided into four parts.

The **first portion** arises from the upper surface of the first part of the subclavian artery, opposite the interval between the longus colli and scalenus anticus, and courses upward and somewhat backward, between these muscles and in front of the transverse process of the seventh cervical vertebra, to the foramen in the transverse process of the sixth cervical vertebra, which it enters. The artery is surrounded by a plexus of sympathetic nerve-fibres, and in front is crossed by the inferior thyroid artery and covered by the vertebral and internal jugular veins. The **second portion** includes the ascent of the artery through the foramina in the transverse process of the upper six cervical vertebræ, surrounded by plexiform networks of sympathetic nerve-fibers and of veins, and lying in front of the trunks of the cervical nerves. As the artery traverses the foramen in the axis it abandons its previous almost vertical course and passes upward and outward to reach the foramen in the atlas. As it emerges from this opening, passing between the suboccipital nerve and the rectus capitis lateralis muscle, its third portion begins, bending horizontally to the outer side and back of the superior articular surface of the atlas to enter the suboccipital triangle (Fig. 522) where it rests in the vertebral groove upon the posterior arch of the atlas, being separated from the bone, however, by the suboccipital nerve. The artery then perforates the lower border of the posterior occipito-atlantoid ligament and enters the spinal canal. The **fourth portion** of the artery pierces the spinal dura mater, passes between the roots of the hypoglossal nerve and the dentate ligament and enters the cranial cavity by traversing the foramen magnum. Passing forward along the medulla oblongata and gradually inclining towards the mid-ventral line, at the posterior border of the pons the vertebral artery unites with its fellow of the opposite side to form the **basilar artery** (**a. basilaris**), which extends forward along the median line of the pons to the anterior border of that structure, where it terminates by dividing into the two posterior cerebral arteries.

Branches.—In its course up the neck the vertebral artery gives off, opposite each intervertebral space which it passes, lateral and medial branches which represent the original segmental arteries by the anastomoses of whose branches the vertebral was formed (page 721).

(*a*) The lateral or **muscular branches** pass to the muscles of the neck and form anastomoses with the ascending and deep cervical branches of the subclavian and with the arteria princeps cervicis of the occipital

(*b*) The medial or **spinal branches** (**rami spinales**) pass through the intervertebral foramina into the spinal canal, accompanying the spinal nerves, and are distributed to the bodies of the vertebræ and to the membranes and substance of the spinal cord. Each branch gives off an *ascending* and a *descending ramus* upon the posterior surface of the spinal cord, and these, anastomosing with each other and with twigs from the spinal branches of the intercostal, lumbar, and lateral sacral arteries below and with the posterior spinal branches of the upper part of the vertebral, assist in the formation of the **posterior spinal arteries**, which run the entire length of the spinal cord upon its posterior surface on each side of the median line. Anteriorly the spinal branches of the vertebral unite with the anterior spinal artery, reinforcing that vessel.

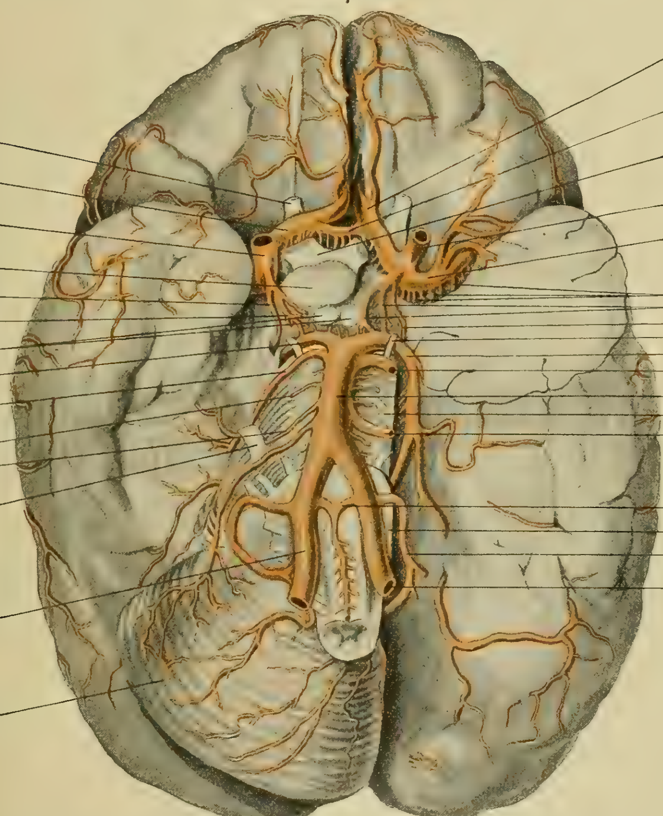
(*c*) The **posterior meningeal artery** (**ramus meningeus**) arises from the vertebral, just after it has pierced the dura mater, and supplies the portion of that membrane which lines the posterior portion of the posterior fossa of the skull.

(*d*) The **posterior spinal artery** (**a. spinalis posterior**) is a slender vessel which anastomoses below with the posterior ascending ramus of the uppermost spinal branch from the cervical portion of the vertebral and forms the uppermost part of the posterior spinal artery.

(*e*) The **anterior spinal artery** (**a. spinalis anterior**), much larger than the preceding, arises from the inner surface of the vertebral, a short distance before the latter unites with its fellow to form the basilar. It passes downward and towards the ventral median line, and unites with its fellow to form a single median longitudinal stem which extends the entire length of the spinal cord along the line of the anterior median fissure, receiving reinforcing branches from the various spinal branches of the vertebral, intercostal, lumbar, and lateral sacral arteries.

(*f*) The **posterior inferior cerebellar artery** (**a. cerebelli inferior posterior**) arises at about the same level as the preceding vessel, but from the outer surface of the vertebral. It passes upward over the sides of the medulla oblongata to supply the lower surface of the cerebellum,

FIG. 702.



Inferior surface of brain, showing internal carotid, vertebral and basilar arteries and circle of Willis; apex of left temporal lobe has been removed to expose ganglionic arteries.

giving branches to the medulla and to the choroid plexus of the fourth ventricle and anastomosing with the superior cerebellar artery.

From the **basilar artery**, (Fig. 702) the anterior median continuation of the vertebrals.

(*g*) Numerous **transverse arteries** are given off and pass outward over the pons to supply that structure and the adjacent portions of the brain.

(*h*) The **internal auditory arteries** (**aa. auditivae internae**), one on each side, are additionally given off, and accompany the auditory nerve through the internal auditory meatus to supply the internal ear.

(*i*) The **anterior inferior cerebellar arteries** (**aa. cerebelli inferiores anteriores**), pass outward on either side over the surface of the pons to the lower surface of the anterior portion of the cerebellum, supplying that structure and anastomosing with the superior cerebellar arteries.

(*j*) The **superior cerebellar arteries** (**aa. cerebelli superiores**). These arise from the basilar, immediately behind its division into the posterior cerebral arteries. They pass outward and backward over the pons and the crura cerebri, immediately behind the roots of the oculo-motor

nerves, and, curving upward in the tentorial fissure almost parallel with the trochlear nerves, are distributed to the upper surface of the cerebellum and anastomose with the inferior cerebellar arteries.

(*k*) The **posterior cerebral arteries** (aa. cerebri posteriores) (Fig. 702) are the terminal branches of the basilar. From its origin at the anterior border of the pons each artery passes outward and slightly forward, curving around the crus cerebri, immediately in front of the root of the oculomotor nerve, which separates it from the superior cerebellar artery. It then passes upon the inferior surface of the cerebral hemisphere, where it breaks up into **cortical branches** which ramify over the surface of the temporal and occipital lobes, anastomosing with one another and with the branches of the anterior and middle cerebrals. The cortical branches (Fig. 700) include the *anterior temporal*, which supplies the anterior parts of the uncinate and occipito-temporal convolutions; the *posterior temporal*, distributed to the posterior part of the uncinate and the occipito-temporal convolutions and the adjoining gyrus lingualis; the *calcarine*, the continuation of the posterior cerebral along the calcarine fissure, which passes to the cuneus and the gyrus lingualis, and winds to the outer surface; and the *parieto-occipital*, which follows the parieto-occipital fissure to the cuneus and the quadrate lobe.

Immediately at their origin the posterior cerebrals give rise to a number of small **central branches** (*postero-mesial* and *postero-lateral ganglionic*) which dip down into the substance of the posterior perforated space to supply the optic thalamus and the adjacent parts of the brain-stem, and somewhat more laterally each gives off a *posterior choroidal* branch, which passes forward in the transverse fissure to the choroid plexus of the third ventricle. Near where it passes in front of the oculo-motor nerve, each posterior cerebral receives the posterior communicating artery which passes back to it from the internal carotid, and more laterally it gives off some small branches which are distributed to the corpora quadrigemina and the posterior part of the optic thalamus.

Variations.—The vertebral artery may arise from a trunk common to it and one of the other branches of the subclavian, and sometimes it arises directly from the arch of the aorta or, on the right side, from the innominate artery or the common carotid. It may traverse a foramen in the transverse process of the seventh cervical vertebra, or the lowest vertebrarterial foramen through which it passes may be the fifth, fourth, third, or even the second. Very rarely the two vertebrals fail to unite to form a single median basilar, that artery being thus represented by two longitudinal trunks united by transverse anastomoses. Occasionally the basilar divides into two longitudinal stems which reunite farther forward, and its formation by the fusion of two parallel vessels is frequently indicated by the presence in its interior of a more or less perfect median sagittal partition.

The vertebral may give origin to an inferior thyroid artery or to the deep cervical, and occasionally, in its upper part, to a branch which anastomoses with the occipital. One of the posterior inferior cerebellar arteries may be wanting, as is also not infrequently the case with one of the anterior inferior cerebellars, or these latter vessels may arise from the posterior cerebral. Occasionally the proximal portion of one or other of the posterior cerebral arteries is reduced to a mere thread, the blood reaching the terminal portions of the vessel from the internal carotid, through the posterior communicating artery.

The Circle of Willis.—The circle or, as it is more properly called, the polygon of Willis (**circulus arteriosus**) is a continuous anastomosis at the base of the brain (Fig. 702) between branches of the internal carotids and subclavians (vertebrals). It surrounds the posterior perforated space and the floor of the thalamencephalon. Posteriorly it is formed by the proximal portions of the posterior cerebral arteries, at the sides by the posterior communicating and internal carotid arteries behind, and by the proximal portions of the anterior cerebrals in front, and it is completed anteriorly by the anterior communicating artery which unites the two anterior cerebrals.

By means of these connections free communication is established at the base of the brain between the two internal carotids and also between these vessels and the vertebrals. It may be noted that a further communication between these sets of vessels exists upon the lateral surfaces of the cerebral hemispheres where branches of the posterior cerebral arteries anastomose with branches of both the middle and anterior cerebrals.

In marked contrast to this abundant anastomosis of the larger vessels upon the surface of the cerebrum is the lack of direct communication between the small vessels which penetrate its substance. These are all terminal or end-arteries,—that is, vessels which have no communication with others except through the general capillary net-work, which offers but little opportunity for the establishment of an efficient collateral circulation in the case of occlusion of one of the arteries.

Practical Considerations.—The vertebral artery may require ligation on account of wounds, or of traumatic aneurism of the vessel itself, or (in addition to the ligation of other vessels) in aortic or innominate aneurism, or to prevent or arrest secondary hemorrhage after ligation of the innominate.

Aneurism—except from wound—is excessively rare, the vessel being well supported, first between the scalenus anticus and the longus colli muscles and then in the bony canal in the transverse processes. Only one case of spontaneous aneurism of the cervical portion of the artery has been reported (Hufschmidt).

Traumatic aneurism is more frequent, but, on account of the vessel's depth, is rare.

Paralysis of some of the tongue muscles has been attributed to pressure on the hypoglossal nerve by a vertebral aneurism and severe occipital headache to pressure on the suboccipital nerve.

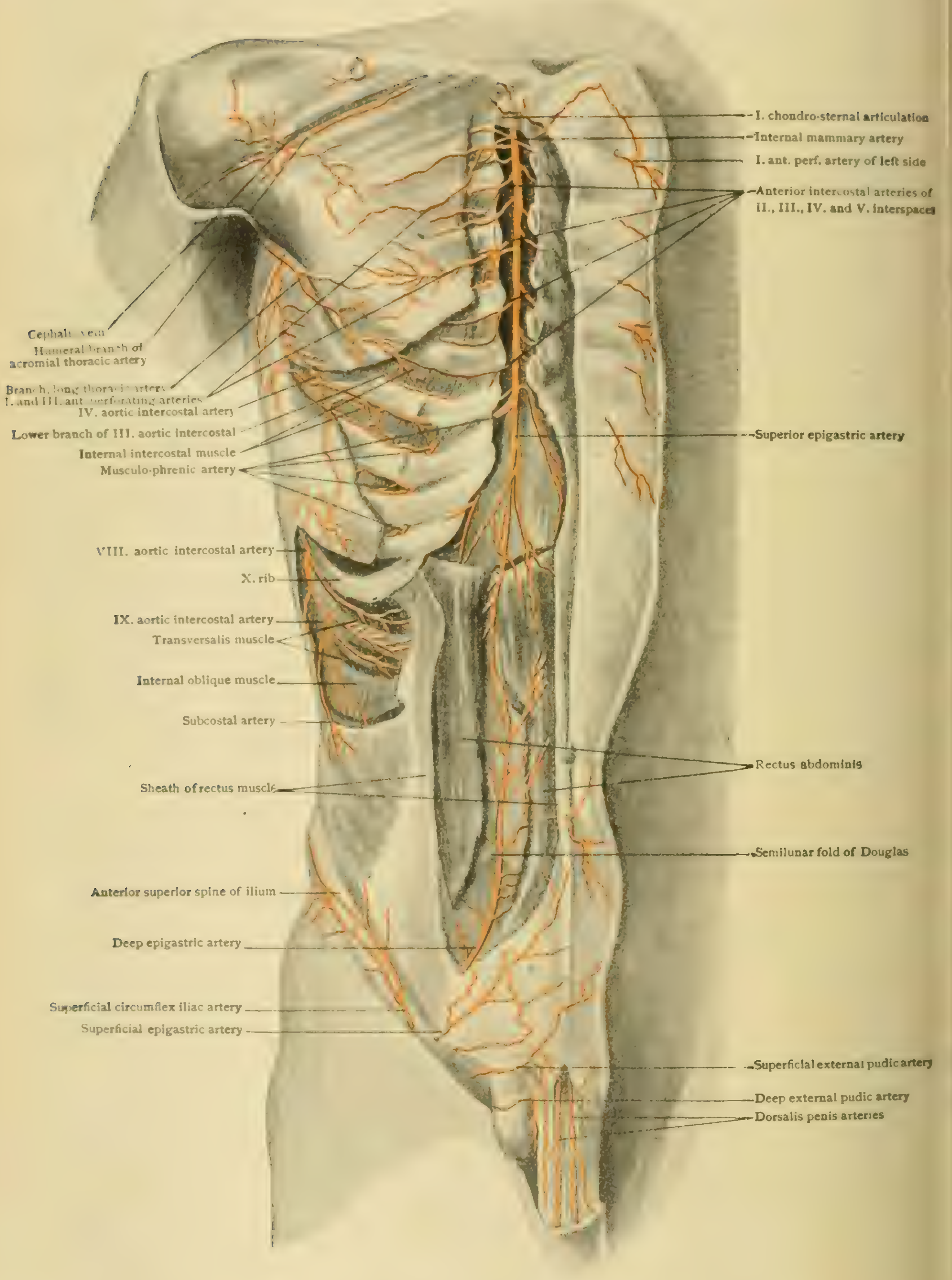
Digital compression of the vertebral is possible below Chassaignac's carotid tubercle (*q.v.*),—*i.e.*, below the level of the cricoid cartilage, if pressure is made in the line of the great vessels. Alternating pressure above and below this level is of great diagnostic value in distinguishing the source of the bleeding, or of the supply of blood to a pulsating tumor, after a deep wound of the neck. Pressure along the line of the common carotid below the tubercle—*i.e.*, for from two to two ana a half inches above the clavicle—will usually arrest such bleeding and pulstaion, no matter whether the vertebral or either of the carotids is involved. Pressure above the tubercle will affect only the carotids and their branches, but—except in the presence of an anomaly—will leave unchanged a flow of blood or an aneurismal pulsation proceeding from the vertebral. Furthermore, as in one of the not infrequent vertebral variations (*vide supra*), the artery may not enter its vertebrarterial foramen until it reaches the fifth, fourth, third, or even the second transverse process, and as, in such a case, it would be effectually compressed when pressure was applied higher than the carotid tubercle, it would be well always to supplement the above test by the method of "lateral compression" (Rouge),—*i.e.*, by pressing together between the thumb and fingers the anterior portion of the relaxed sterno-mastoid muscle and the carotid sheath and its contents. This avoids all risk of coincident compression of the vertebral, and if it arrests the temporal pulse without affecting materially the bleeding or the pulsation on account of which the examination is made, it greatly increases the probability that the latter are of vertebral origin (Matas). The importance of making the diagnosis is shown by the fact that in sixteen out of thirty-six cases of injuries to the vertebral artery the common carotid had been ligated, aggravating the hemorrhage by increasing the strain on the vertebral circulation and, of course, also increasing the risk from shock, and later from cerebral complications (Matas).

Ligation of the vertebral has been effected through variously placed incisions: 1. Low in the neck, one of three inches in length along the posterior border of the sterno-mastoid and with its lower end at the clavicle, with division of some of the clavicular fibres of that muscle and of the deep fascia, will permit the recognition of the carotid tubercle, the displacement inward of the sterno-mastoid and internal jugular vein, the definition of the space between the scalenus anticus and the longus colli, and the identification of the artery by its pulsation. The vertebral vein lies in front of the artery. The pleura, the inferior thyroid vessels, the phrenic nerve, and on the left side the thoracic duct must be avoided. The fibres of the cervical sympathetic will be almost necessarily disturbed, and may be included in the ligature. Contraction of the corresponding pupil, through the then unopposed action of the oculomotor, will indicate that the vessel has been secured; it will be only temporary.

2. For a ligation in continuity, as for wound or aneurism in the suboccipital region, the artery may be much more easily reached through an incision identical with that used for ligating the common carotid above the omo-hyoid (page 732). When the carotid sheath is well exposed it is drawn outward with its contents. Chassaignac's tubercle is felt (on the cricoid level or one centimetre above it) and the longus colli fibres below, overlying the artery, are seen. A transverse division of that muscle exposes the vertebral artery in a much safer region than below and at a less depth (Dawbarn).

The *collateral circulation* is very freely re-established through the vessels of the circle of Willis.

FIG. 703.



Internal mammary and deep epigastric arteries.

2. **The Internal Mammary Artery.**—The internal mammary artery (**a. mammaria interna**) (Figs. 692, 703) arises from the lower surface of the subclavian, usually a few millimetres lateral to the origin of the vertebral. It is at first directed downward, inward and slightly forward to reach the posterior surface of the first costal cartilage, about half-an-inch lateral to the border of the sternum, and is thence continued vertically downward upon the inner surface of the anterior thoracic wall to the sixth intercostal space, opposite which it terminates by dividing into the musculo-phrenic and superior epigastric arteries.

In the upper part of its course the artery rests upon the dome of the pleura, crosses the posterior surface of the subclavian vein, and is crossed obliquely from above downward and inward by the phrenic nerve. In the thorax it is in contact behind with the parietal layer of the pleura as far down as the third costal cartilage, and below that with the triangularis sterni muscle. Anteriorly it rests upon the posterior surfaces of the upper five costal cartilages, and, in the intercostal spaces, upon the anterior portions of the internal intercostal muscles.

Branches.—The internal mammary gives off the following branches: (1) the *superior phrenic*, or *comes nervi phrenici*, (2) the *mediastinal* branches, (3) the *anterior intercostals*, (4) the *anterior perforating* branches and the two terminal branches, (5) the *musculo-phrenic*, and (6) the *superior epigastric*.

(*a*) The **superior phrenic artery** or **comes nervi phrenici** (**a. pericardiacophrenica**) arises from the upper part of the internal mammary, and is a long, slender branch which accompanies the phrenic nerve to the diaphragm, where it anastomoses with the inferior phrenic and musculo-phrenic vessels. In its course it gives off numerous small branches to the pleura and pericardium, which anastomose with the mediastinal branches and the bronchial vessels from the thoracic aorta.

(*b*) The **mediastinal branches** (**aa. mediastinales anteriores**) are a number of small vessels which are distributed to the sternum, the remains of the thymus gland, the pericardium, and the adipose tissue of the anterior mediastinum.

(*c*) The **anterior intercostal arteries** (**rami intercostales**) arise from the internal mammary opposite each of the five upper intercostal spaces, and are two in number for each space. They pass outward and slightly downward upon the posterior surface of the intercostal muscles, one along the upper border of each of the intercostal spaces concerned and the other along its lower border, and after having pierced the internal intercostal muscles, they terminate by becoming continuous with the upper and lower divisions respectively of the intercostal branches of the superior intercostal artery and of the three uppermost aortic intercostals. These branches really represent ventral prolongations of the aortic intercostal arteries from which arose the upward and downward branches whose anastomosis resulted in the formation of the internal mammary (compare page 848).

(*d*) The **anterior perforating branches** (**rami perforantes**) arise from the internal mammary, one opposite each intercostal space that it crosses, and represent the ventral ends of the original aortic intercostal. They pierce the internal intercostal muscles, the anterior intercostal membrane, and the pectoralis major, to supply branches to the sternum and to the integument. The arteries of the third and fourth intercostal spaces are larger than the others and send branches to the mammary gland.

(*e*) The **musculo-phrenic artery** (**a. musculophrenica**) is the lateral terminal branch of the internal mammary. It arises opposite the anterior end of the sixth intercostal space and passes downward and outward along the attachments of the diaphragm to the seventh and eighth costal cartilages, and then, piercing the diaphragm, is continued onward upon the under surface of that muscle to the level of the tenth or eleventh rib, where it terminates by anastomosing with the inferior phrenic arteries and with the ascending branch of the deep circumflex iliac. In addition to branches to the diaphragm, it gives off two anterior intercostal branches opposite each of the intercostal spaces that it crosses as far down as the ninth; these branches have the same arrangement and significance as the anterior intercostal branches of the internal mammary.

(*f*) The **superior epigastric artery** (**a. epigastrica superior**) is the medial terminal branch of the internal mammary. It continues the course of that artery downward, and passes through the diaphragm in the interval between its costal and sternal origins and enters the sheath of the rectus abdominis. Lower down it passes into the substance of that muscle, where it terminates by anastomosing with branches of the deep epigastric artery.

Anastomoses.—By means of its terminal branches the internal mammary makes a double anastomosis in the anterior abdominal walls with branches from the iliac vessels,—namely, with the deep epigastric and deep circumflex iliac branches of

the external iliac, and thus connects the superior and inferior portions of the aortic system of vessels. In addition, by means of the anterior intercostals, it makes extensive connections with the thoracic aorta through the aortic intercostals.

Variations. The internal mammary may arise from the second or even the third portion of the subclavian, or it may take its origin from the thyroid axis or from the superior intercostal. In its course down the anterior thoracic wall it varies considerably in its relation to the lateral border of the sternum, its distance from it varying in different cases from 5–20 mm.

Of the supernumerary branches to which it may give rise, one of the most important is the *lateral internal mammary* (ramus costalis lateralis). This arises from the internal mammary above the first rib, or in some cases directly from the subclavian, and descends upon the inner surfaces of the upper four or six ribs and the intervening intercostal spaces, parallel with the internal mammary, but some distance lateral to it. It gives off branches in each intercostal space, which anastomose ventrally with the anterior intercostal branches of the internal mammary and dorsally with the aortic intercostals.

Practical Considerations.—The internal mammary is not infrequently involved in stab wounds of the chest, and this accident may be suspected if after such a wound there are threatening symptoms of internal hemorrhage with no evidence of injury to the lung itself. The bleeding may take place into the pleural cavity, causing the characteristic symptoms of hæmothorax (page 1866).

Compression.—In emergencies the bleeding may sometimes be arrested by pushing through the wound into the intrathoracic space or pleural cavity a pouch of antiseptic gauze, packing it with other strips of gauze so as to distend the portion within the ribs, and then making traction upon it so as to compress the wounded vessel against the costal cartilages and the chest-wall.

This same method is applicable in some cases of *intercostal* hemorrhage when it is not possible or desirable to approach the vessel directly in its groove on the under and inner border of the rib by incision or by resection of a portion of the rib.

Ligation.—In some cases it may be necessary to ligate the vessel in its continuity, although its free anastomoses make it very desirable to find and tie it on both sides of the wound. It may be reached through an incision parallel with the sternum and a half-inch from its margin or through a transverse incision extending outward along an intercostal space. In either event, the skin, superficial fascia, sternal fibres of the great pectoral muscle, the external intercostal aponeurosis (connecting the external intercostal muscle with the sternum), and the internal intercostal muscle must be divided. The artery with its accompanying veins will be found in loose cellular tissue lying, in the first two spaces, upon the endothoracic fascia, which separates it from the pleura; in the lower spaces the vessel rests upon the triangularis sterni muscle. Below the third or fourth space resection of a cartilage will usually be necessary for the purpose of gaining room, and at any level is often resorted to to permit direct access to the bleeding ends.

3. **The Superior Intercostal Artery.**—The superior intercostal artery (truncus costocervicalis) (Fig. 695) arises from the upper posterior surface of the subclavian artery, usually about opposite the origin of the internal mammary, but quite frequently, and especially upon the right side, under cover of the scalenus anticus. It passes at first upward and medially, and then curves backward and downward over the dome of the pleura to reach the anterior surface of the neck of the first rib, where it divides into two terminal branches which pass laterally in the first and second intercostal spaces. As it enters the thorax, the superior intercostal lies between the first thoracic sympathetic ganglion and the first thoracic spinal nerve.

Branches.—The superior intercostal gives rise to (1) the *deep cervical artery*, and to two terminal branches, (2) the *first* and (3) the *second intercostal arteries.*

(*a*) The **deep cervical artery** (a. cervicalis profunda) arises just as the superior intercostal reaches the upper border of the neck of the first rib, although occasionally it takes origin directly from the subclavian. It is directed upward and backward, passing between the last cervical and first thoracic nerves and beneath the transverse process of the last cervical vertebra, and ascends the neck between the complexus and the semispinalis colli, to which it sends branches. It anastomoses with branches of the ascending cervical, vertebral, and princeps cervicis arteries, and gives off a spinal branch which passes along the eighth cervical nerve to the

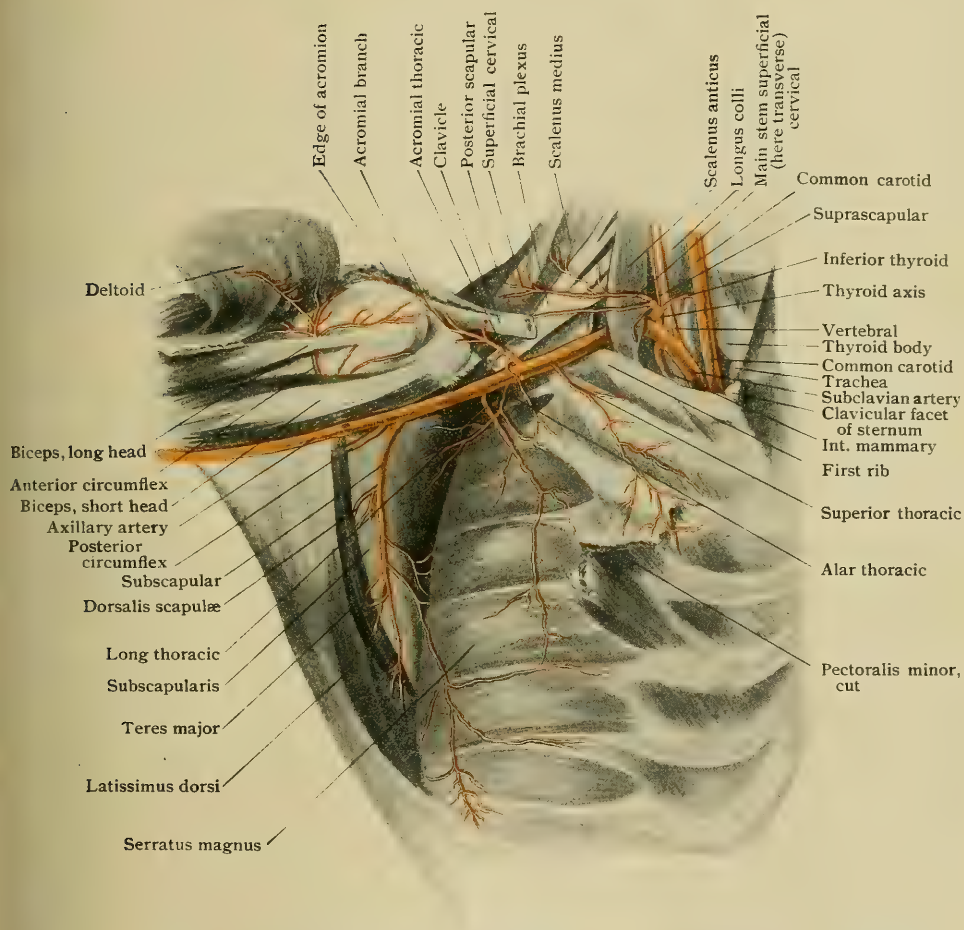
spinal canal, where it anastomoses upon the surface of the spinal cord with the spinal branches of the vertebral and of the intercostal arteries.

In all its relations the deep cervical is comparable to a posterior branch of an intercostal artery, and is to be regarded as the posterior branch of the seventh cervical segmental artery, which is the subclavian.

(*b*) The **first intercostal artery** passes outward and forward in the first intercostal space, and resembles in its course and distribution an aortic intercostal (page 792).

(*c*) The **second intercostal artery** arises at the bifurcation of the superior intercostal and passes downward over the neck of the second rib to the second intercostal space, in which it

FIG. 704.



Deep dissection exposing subclavian and axillary arteries and their branches.

courses similarly to an aortic intercostal (page 792). It usually receives an anastomosing branch from the third intercostal artery or else directly from the thoracic aorta, and may be replaced by it.

Variations.—The superior intercostal may arise from the vertebral artery and may terminate in the first intercostal alone, the second arising from the third or from the thoracic aorta. Anastomoses occur between the first and second intercostals and the arteria aberrans (page 792), when that vessel is present.

4. **The Thyroid Axis.**—The thyroid axis (**truncus thyreocervicalis**) (Fig. 704) arises from the upper border of the subclavian, usually just medial to the medial border of the scalenus anticus. It ascends vertically upward for from 2–10 mm.,

and terminates by dividing into three branches: (1) the *inferior thyroid*, (2) the *superficial cervical*, and (3) the *suprascapular*.

(*a*) The **inferior thyroid artery** (**a. thyreoidea inferior**) (Fig. 692) is the largest of the branches which arise from the thyroid axis. It passes at first vertically upward to about the level of the transverse process of the sixth cervical vertebra, and then bends medially. It passes behind the common carotid artery, the internal jugular vein, and the pneumogastric nerve, either behind or in front of the recurrent laryngeal nerve and in front of the vertebral artery, and finally breaks up into branches which supply the lower part of the thyroid gland and anastomose with their fellows of the opposite side and with the superior thyroid artery.

Branches.—In addition to these terminal branches, the inferior thyroid gives origin to the following arteries:

(*aa*) **Muscular branches** to the scalenus anticus and the inferior constrictor of the pharynx.

(*bb*) The **ascending cervical artery** (**a. cervicalis ascendens**) frequently arises directly from the thyroid axis and passes vertically upward, parallel to the phrenic nerve, in the interval between the scalenus anticus and the rectus capitis anticus major. It supplies the deep muscles of the neck, sends branches through the spinal foramina which accompany the spinal branches of the vertebral artery, and anastomoses with the vertebral, the occipital, the ascending pharyngeal, and the deep cervical arteries.

(*cc*) The **inferior laryngeal artery** (**a. laryngea inferior**) passes upward in the groove between the trachea and œsophagus in company with the recurrent laryngeal nerve. It passes beneath the lower border of the inferior constrictor of the pharynx and enters the larynx, to whose mucous membrane and muscles it is distributed. It anastomoses with the superior laryngeal branch of the superior thyroid.

Finally, it gives off small branches to the pharynx, œsophagus, and trachea, one of those to the last-named structure extending down upon its lateral surface to anastomose below with the bronchial arteries.

The anastomoses which the inferior thyroid makes by its thyroid branches with the superior thyroid and by its ascending cervical branch with the occipital constitute important connections between the subclavian and carotid systems and play an important part in the establishment of the collateral circulation after ligation of the common carotid artery.

Variations.—The thyroid axis occasionally arises under cover of or even lateral to the scalenus anticus, and it may be entirely wanting, its branches arising directly from the subclavian. The inferior thyroid may be absent on one side or on both, and its size varies inversely to the development of its fellow of the opposite side or to that of the superior thyroid arteries.

Practical Considerations.—The inferior thyroid may be tied for a wound or during the operation of thyroidectomy. It has been frequently tied, in conjunction with the superior thyroid, in various forms of goitre, but the procedure has been abandoned. It may be reached through the incision for tying the carotid below the omo-hyoid (page 732). The sterno-mastoid and the carotid sheath and its contents are drawn outward. The carotid tubercle being found, the inferior thyroid should be sought for at a slightly lower level,—opposite the body of the sixth cervical vertebra or about the level of the omo-hyoid crossing,—coming out from behind the sheath of the great vessels and running in front of the vertebral artery obliquely upward and inward towards the gland. It should be remembered that before entering the gland it lies for a short distance close to its posterior surface, and that the recurrent laryngeal nerve is in intimate relation to this part of the vessel or to its terminal branches. It should therefore be tied in the fissure between the œsophagus and the great vessels, as close to the carotid sheath—*i.e.*, as far from the inferior angle of the gland—as possible, to avoid inclusion of this nerve. The middle cervical ganglion of the sympathetic, the phrenic and the descendens hypoglossi nerves, and, on the left side, the thoracic duct should be carefully avoided.

(*b*) The **superficial cervical artery** (**a. cervicalis superficialis**) (Fig. 705) passes almost directly laterally from the thyroid axis, passing in front of the scalenus anticus and then across the lower part of the posterior triangle of the neck at a level of about 2.5 cm. above the clavicle. Arrived at the anterior border of the trapezius, it passes beneath that muscle and breaks up into ascending and descending branches which supply the trapezius, the levator anguli scapulæ, the rhomboidei, and the

splenii. The ascending branches anastomose with the deep and ascending cervical arteries, and with the princeps cervicis of the occipital and the descending branches with the suprascapular and transverse cervical.

(*c*) The **suprascapular artery** (a. transversa scapulæ) (Fig. 704), like the superficial cervical, passes almost directly laterally across the lower part of the posterior triangle of the neck. It lies, however, on a somewhat lower level than, and anterior to, the superficial cervical, lying usually behind the clavicle, in front of the subclavian artery, and resting below upon the subclavian vein. It is continued laterally beneath the trapezius, to which it sends branches, and, having reached the upper border of the scapula, it passes over the transverse ligament of that bone, or occasionally through the suprascapular notch, into the supraspinous fossa. Here it gives branches to the supraspinatus muscle, and, winding around the lateral border of the spine, passes through the scapular notch into the infraspinous fossa, where it breaks up into branches supplying the infraspinatus muscle and anastomosing abundantly and widely with the branches of the dorsal scapular artery.

5. **The Transverse Cervical.**—The transverse cervical (a. transversa colli) is the only branch which arises from the third portion of the subclavian. It also is directed laterally, parallel with the superficial cervical and suprascapular arteries, about midway between them, but on a much deeper level. It rests upon the anterior surface of the scalenus medius muscle, and upon the trunks of the brachial plexus, and, passing beneath the posterior belly of the omo-hyoid, reaches the lower portion of the levator anguli scapulæ, beneath which it terminates by dividing into ascending and posterior scapular branches.

Branches.—In addition to the two terminal branches, the transverse cervical gives off branches to the trapezius, the supraspinatus, and the levator anguli scapulæ muscles.

(*a*) The **ascending terminal branch** (ramus ascendens) passes upward to supply the splenius muscles, and forms anastomoses with the superficial cervical.

(*b*) The **posterior scapular artery** (ramus descendens) descends along the entire length of the vertebral border of the scapula beneath the rhomboid muscles. It supplies these muscles and the serratus posticus superior, and sends branches laterally upon both the dorsal and ventral surfaces of the scapula, supplying the infraspinatus and subscapular muscles and anastomosing with the dorsal scapular and subscapular arteries

Anastomoses.—The anastomoses which the suprascapular and transverse cervical arteries make with the branches of the subscapular artery from the axillary are of considerable importance in the establishment of the collateral circulation from the arm after ligation of the third portion of the subclavian. Additional paths which may be employed for the same purpose are afforded by the anastomoses which occur between the thoracic branches of the axillary artery and the intercostal branches of the superior intercostal, and more especially the perforating branches of the internal mammary.

Variations.—Very frequently indeed the anastomosis which exists between the ascending branch of the transverse and the superficial cervical develops to such an extent that it forms the principal channel by which the blood reaches the posterior scapular from the subclavian, and in such cases the main stem of the transverse cervical disappears, the posterior scapular then becoming a terminal branch of the superficial cervical. This arrangement (Fig. 705) is of such frequent occurrence that it is regarded as the normal one by many authors. When this is done, the name, transverse cervical, is applied to the main stem of the superficial cervical, the latter term being retained for and limited to the ascending branch of the original artery. When this arrangement obtains, there is no branch from the third portion of the subclavian artery.

THE AXILLARY ARTERY.

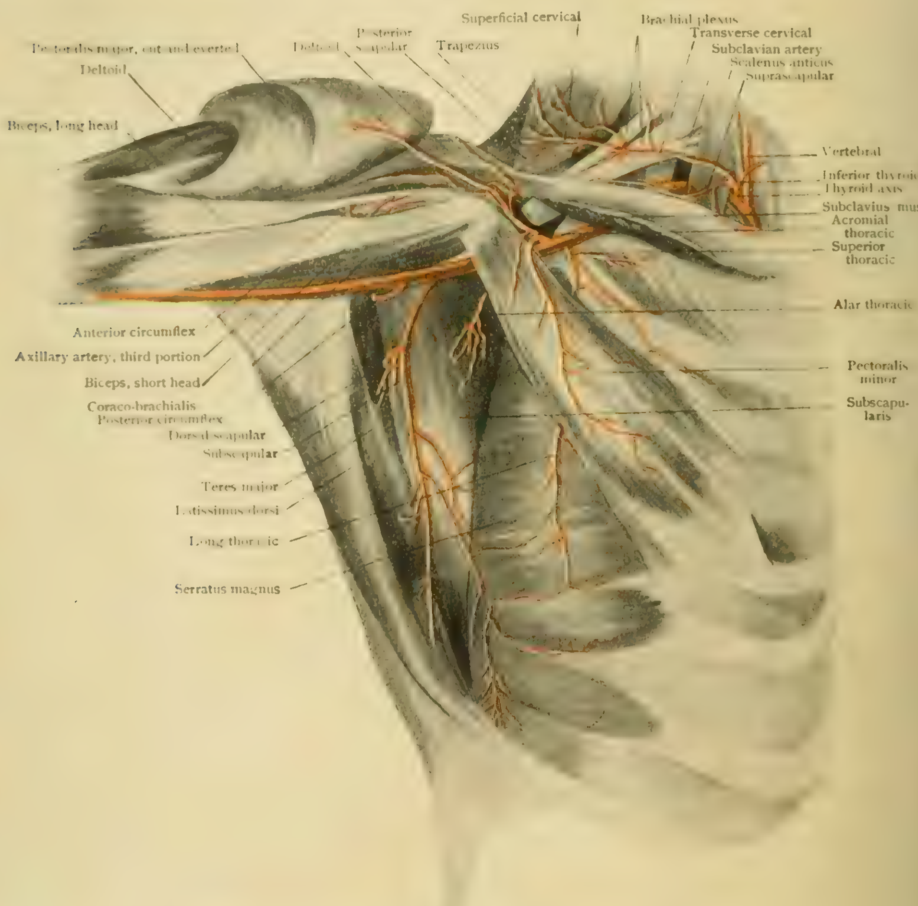
The axillary artery (a. axillaris) (Figs. 704, 705) is the continuation of the subclavian through the axillary space. It begins at the lower border of the first rib, at the apex of the axillary space, and passes downward along the outer wall of the space to the lower border of the teres major, where it becomes the brachial artery. When the arm is abducted to a position at right angles to the axis of the trunk, the artery has an almost straight course, which may be represented by a line drawn from the middle of the clavicle to a point midway between

the two condyles of the humerus. When, however, the arm hangs vertically, the vessel is slightly curved, the convexity of the curve looking upward and outward.

Relations.—For convenience in description it is customary to regard the axillary artery as consisting of three portions, the first of which is above the upper border of the pectoralis minor, the second behind that muscle and the third below its lower border.

The **first portion** of the artery is covered anteriorly by the clavicular portion of the pectoralis major, by the costo-coracoid membrane which separates it from the cephalic vein and the branches of the acromio-thoracic artery, and by the subclavius muscle. The artery is enclosed along with its accompanying vein and the cords of

FIG. 705.



Subclavian and axillary arteries pectoralis minor still in place.

the brachial plexus in a downward prolongation of the cervical fascia known as the *axillary sheath*, and rests behind upon the upper serration of the serratus magnus and upon the first intercostal space. The internal anterior thoracic and the posterior thoracic nerves cross it obliquely behind, the latter nerve intervening between it and the serratus magnus. Above, at the outer side, are the cords of the brachial plexus and the external anterior thoracic nerve, and below and to the inner side is the axillary vein, between which and the artery is the internal anterior thoracic nerve.

In its **second portion** the artery is covered anteriorly by both the pectoralis major and the pectoralis minor. Posteriorly it lies in contact with the posterior cord of the brachial plexus, and is separated by a quantity of areolar and fatty tissue from

the anterior surface of the subscapularis muscle. External to it is the outer cord of the brachial plexus, and internally the inner cord, which separates it from the axillary vein.

In its **third portion** the artery is covered in its upper half by the lower part of the pectoralis major, but in its lower half only by the integument and the superficial and deep fasciæ. The inner head of the median nerve passes obliquely across its anterior surface. Posteriorly it is in relation with the subscapularis, latissimus dorsi, and teres major, in that order from above downward, a considerable amount of areolar tissue, in which run the circumflex and musculo-spiral nerves, intervening, however, between the artery and the muscles. To the outer side are the median and musculo-cutaneous nerves and the coraco-brachialis muscle, while internally are the internal cutaneous and ulnar nerves and the axillary vein.

Branches.—Much variation occurs in the arrangement of the branches of the axillary artery. It is customary to recognize seven branches, but one or more of them is frequently absent as a distinct branch arising directly from the artery. These branches are arranged as follows: from the **first part** are given off (1) the *superior thoracic* and (2) the *acromial thoracic*; from the **second part** (3) the *long thoracic* and (4) the *alar thoracic*; and from the **third part** (5) the *subscapular*, (6) the *anterior circumflex*, and (7) the *posterior circumflex*.

Variations.—As stated in the description of the variations of the subclavian, the axillary artery may be represented by two parallel vessels which arise from the first portion of the subclavian and are continued below into the radial and ulnar arteries. The more frequent variations, however, concern the occurrence of additional branches from the axillary, and of these there may be mentioned the occurrence of the superior profunda, normally a branch of the brachial, but not infrequently arising from the axillary in common with the subscapular.

Practical Considerations.—The axillary artery may require to be ligated on account of wounds, of rupture, of high aneurism of the brachial, or, rarely, in distal ligation for subclavian aneurism.

Wounds of the axillary are not uncommon when the vulnerating body—a knife-blade, a bullet, etc.—is directed from within outward, the artery in all positions of the arm maintaining a much closer relation to the outer, or humeral, wall of the axilla than to the inner, or thoracic, wall, which is therefore known as the wall of safety. It is always well in such cases to expose the artery and to tie both ends, as the exact source of the bleeding is often necessarily in doubt and the free anastomosis of its branches is likely to lead to secondary hemorrhage from the wound if the vessel is tied in continuity.

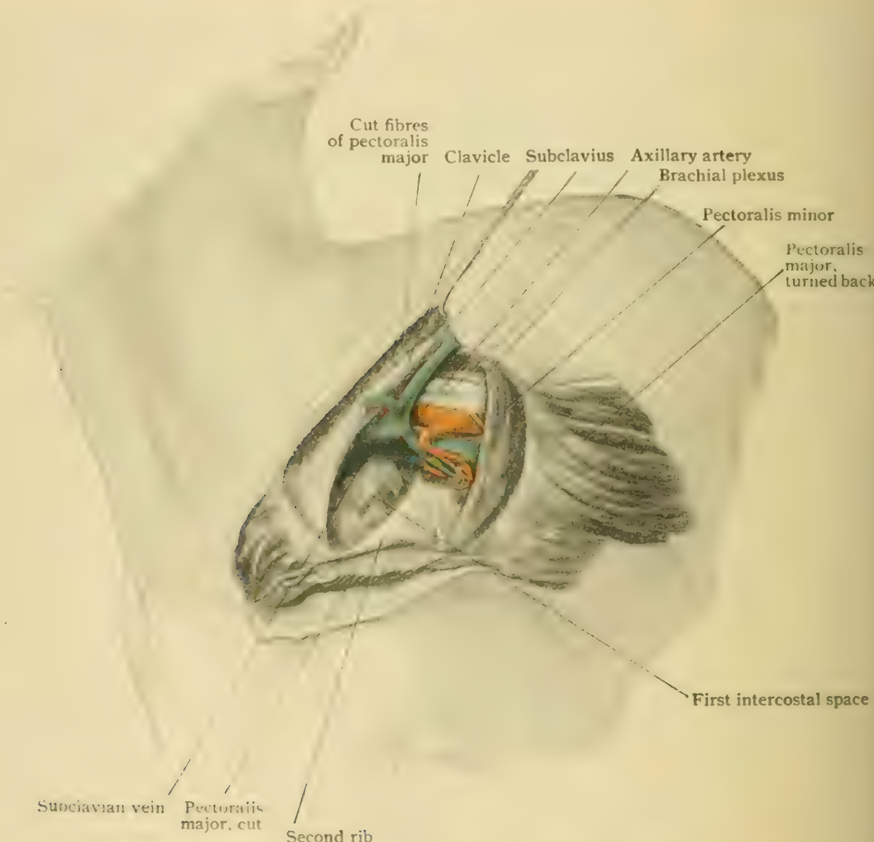
Rupture of the axillary artery has occurred in a considerable number of cases as an accident due to the movements employed in attempted reduction of old dislocations of the shoulder. The preponderance of arterial as compared with venous rupture (twenty-six out of twenty-eight cases, Stimson; or forty out of forty-four, Körte) is striking, the greater thinness of the vein and its attachment to the costo-coracoid membrane—circumstances that would seem to favor its rupture—being more than counterbalanced by the greater frequency and extent of atheromatous degeneration and consequent loss of elasticity in the artery, and possibly by the greater liability of the latter to undergo tension during the movements of abduction, elevation, and circumduction (which are those chiefly associated with the accident in question), and—as the outermost or rather uppermost vessel—to contract adhesion to the displaced humeral head.

Aneurism of the axillary is comparatively frequent, as might be expected from the number, variety, and range of the movements of the shoulder-joint, during which the vessel is subjected to strains and to a variety of flexures. It is more common on the right side on account of the more general use of the right arm, and affects oftenest the third portion of the vessel, or that least supported by surrounding structures and most subjected to changes in tension and position and to certain injuries, as those which occur during luxation of the shoulder or during efforts at reduction (*vide supra*). On account of the looseness of the tissue in which it lies, such an aneurism rapidly attains a large size and, by reason of the minor traumatisms inflicted during the shoulder movements, is especially prone to inflammation.

The *symptoms* are (*a*) *swelling* showing immediately below the clavicle (in Mohrenheim's fossa) and pushing that bone upward if the first portion is involved, or pushing the pectoral muscles forward if the aneurism is lower, or appearing as a pulsating tumor in the axilla if the third portion is involved; (*b*) *œdema* of the arm and hand from pressure on the axillary vein; (*c*) *pain* down the arm, in the shoulder and neck, and down the side of the chest, and *feebleness and limitation* of shoulder and arm movements from, first, spasm, then paresis of the associated muscles, all due to pressure on the brachial plexus and its branches.

Digital compression of the axillary artery is only effectively possible in the lower part of the third portion, where, with the fingers beneath the anterior axillary fold,

FIG. 706



Dissection showing relations of axillary artery in first part of its course.

the vessel, if the effort is made with due care and gentleness, may be flattened against the humerus just within the edge of the coraco-brachialis and biceps.

Ligation of the *first portion* may be effected in two ways: 1. With the arm abducted to a right angle, an incision three inches long, slightly convex downward, and with its centre about an inch below the middle of the clavicle, is made through the skin, superficial fascia, and platysma. The cephalic vein and the descending branch of the acromial thoracic artery will be seen, just beneath the fascia, in the groove between the deltoid and greater pectoral muscles. The outer clavicular fibres of the pectoralis major are then divided close to the clavicle; the interpectoral and axillary fascia and some loose connective tissue are broken up; the upper border of the pectoralis minor is identified and traced to the coracoid process; the costo-coracoid membrane is cautiously cut through by a vertical incision close to the coracoid; the artery is then sought for, lying between the brachial plexus of nerves externally and

the vein internally. The internal anterior thoracic nerve is sometimes seen coming out between the vein and the artery. The arm should be brought to the side to relieve tension on the vessels, especially the vein, which in that position will be least prominent. The needle should be passed from within and below outward and upward.

2. With the arm abducted, so as to make evident the fissure between the sternal and clavicular portions of the pectoralis major, an oblique incision is made over this space and will usually begin about a half-inch from the sterno-clavicular joint. The muscular interspace having been exposed, its sides are separated, not directly backward, but backward and upward towards the clavicle. The arm is brought to the side to relax the pectoral fibres. The pectoralis minor and the space between it and the clavicle are reached, and if the latter is too contracted, the muscle may be divided close to the coracoid process. The artery is then exposed and secured as in the method above given.

The *second portion* is not formally ligated, but may have a ligature applied whenever, as in the last-mentioned method, the lesser pectoral has been divided.

Ligation of the third portion of the subclavian artery is, on account of its ease of performance, almost invariably preferred to any of these operations.

The *third portion* of the axillary is that almost always selected for ligation of that vessel, for a similar reason.

The line of the vessel, the arm being at right angles to the trunk, is from the junction of the anterior and middle thirds of the summit of the axilla to the middle of the bend of the arm at the elbow. This line will be found to follow the inner margin of the coraco-brachialis muscle, the prominence of which may be seen just internal to the swell of the biceps where it emerges from beneath the anterior axillary fold. An incision is made on this line through the skin and superficial and deep fasciæ, and the fibres of the coraco-brachialis margin are exposed and cleared. Internally to them lies the vessel, the median and musculo-cutaneous nerves external to it, and the internal cutaneous nerve and axillary vein on its inner side.

The needle should be passed from within outward.

The *collateral circulation* is established after ligation of the *first portion* above the origin of the acromial thoracic precisely as after ligation of the third portion of the subclavian (page 757). After ligation of the *third portion* above the origin of the subscapular the anastomoses take place between (*a*) the intercostals, long thoracic, posterior scapular, and suprascapular, and (*b*) the acromial thoracic, on the cardiac side of the ligature ; and (*a*) the subscapular, and (*b*) the posterior circumflex on the distal side.

When the vessel has been tied between the origins of the subscapular and the two circumflex arteries—probably the point of election (Taylor)—the anastomoses occur between the branches of the axillary and those of the thyroid axis,—*i.e.*, the suprascapular and acromial thoracic above and the posterior circumflex below. Still lower,—*i.e.*, below the circumflex arteries—the collateral circulation is established just as after ligation of the brachial above the superior profunda (*q.v.*).

1. **The Superior Thoracic Artery.**—The superior or short thoracic (a. **thoracalis suprema**) (Fig. 704) arises just after the axillary has emerged from beneath the subclavius muscle, and is directed downward and forward to the first intercostal space, the muscles of which it supplies. Not infrequently it gives off a branch which supplies the muscles of the second intercostal space also. Its branches anastomose with those of the internal mammary and acromial thoracic, and occasionally its place is taken by a branch from the latter vessel.

2. **The Acromial Thoracic Artery.**—The acromial thoracic (a. **thoraco-acromialis**) (Fig. 705) is a very constant branch which arises from the front of the axillary artery, a short distance below the superior thoracic. It is directed forward for a short distance, but soon divides into thoracic, clavicular, and acromio-humeral branches.

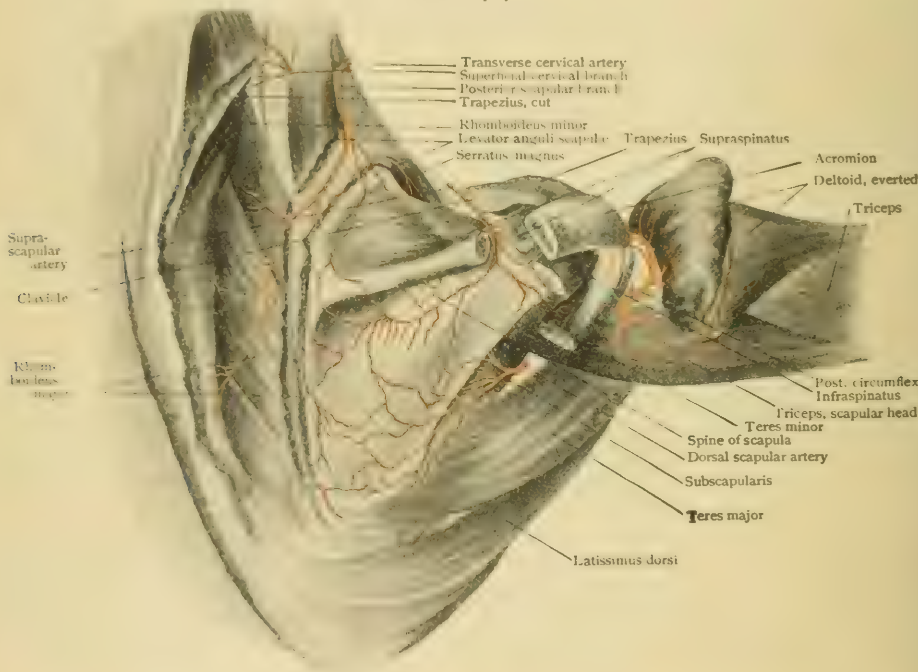
Branches.—(*a*) The **thoracic branches** (**rami pectorales**) pass downward and forward to the side of the thorax, supplying the muscles of the second and third, and sometimes of the fourth and fifth intercostal spaces, and also giving branches to the pectoralis major and the pectoralis minor. It anastomoses with the intercostal arteries and the superior and long thoracics.

(*b*) The clavicular branch, which is the smallest of the three, passes upward to supply the subclavius muscle, and anastomoses with the suprascapular artery.

(*c*) The acromio-humeral branch passes upward and outward across the costo-coracoid membrane and over the coracoid process of the scapula, and then divides into an *acromial* and a *humeral* branch. The former (**ramus acromialis**) passes upward towards the acromial process to supply the deltoid muscle, while the latter (**ramus deltoideus**) turns downward in the groove between the deltoid and the clavicular portion of the pectoralis major, accompanying the cephalic vein. It sends branches to the two adjacent muscles and to the integument, and anastomoses with the anterior circumflex artery.

3. **The Long Thoracic Artery.**—The long thoracic (**a. thoracica lateralis**) (Fig. 704) is a somewhat inconstant branch, whose place is very frequently taken by the thoracic branch of the acromial thoracic or by a branch from the subscapular. It passes downward and forward upon the serratus magnus, sending branches to that muscle, the pectoralis minor, and the muscles of the third, fourth, and fifth intercostal

FIG. 707.



Arteries of posterior aspect of shoulder.

spaces. It also sends branches to the mammary gland (**rami mammarii externi**), whence it has been termed the *external mammary* artery. It anastomoses with the thoracic branch of the acromial thoracic, with the subscapular and the intercostals, and with the perforating branches of the internal mammary.

4. **The Alar Thoracic Artery.**—The alar thoracic (Fig. 704) is a very inconstant small branch which passes to the fascia and lymphatic glands of the axillary space. Its place may be taken by branches from the subscapular, the long thoracic, or the thoracic branch of the acromial thoracic.

5. **The Subscapular Artery.**—The subscapular (**a. subscapularis**) (Fig. 704) is the largest branch of the axillary and arises just as that artery crosses the lower border of the subscapularis muscle. It passes downward and inward, accompanied by the long subscapular nerve, along the lower border of the subscapular muscle as far as the lower angle of the scapula, and distributes branches throughout its course to the subscapularis and teres major and to the latissimus dorsi. It also gives off—

(*a*) **Thoracic branches** (**rami thoracodorsales**), which supply the serratus magnus and the muscles of some of the intercostal spaces, and not far from its origin it gives off—

(*b*) The **dorsal scapular** (**a. circumflex scapulae**). This vessel, of large size, winds around the axillary border of the scapula in the triangular space bounded by the teres major, the teres minor, and the long head of the triceps, and is distributed to the infraspinatus and the teres minor.

The subscapular artery anastomoses through its thoracic branches with the intercostals and with the long thoracic, and through the dorsal scapular with the suprascapular and posterior scapular arteries.

Variations.—The subscapular artery varies somewhat in its origin. Occasionally it springs from the second portion of the axillary, and may also arise from the brachial. Quite frequently it arises from a trunk common to it and one or other or both circumflex arteries, and the superior profunda brachii, normally a branch of the brachial artery, may also arise from this common trunk.

The subscapular has been observed to give rise to an aberrant artery which passes down the arm and either unites with the brachial or else becomes the ulnar, or may even extend to the neighborhood of the wrist, where it unites with a branch of the anterior interosseous artery to form the radial.

6. **The Anterior Circumflex Artery.**—The anterior circumflex (**a. circumflexa humeri anterior**) (Fig. 704) is the smallest of the three branches of the third portion of the axillary, and arises either directly from the artery or from a common trunk with the posterior circumflex ; more rarely it arises from the subscapular. It passes outward beneath the coraco-brachialis and the heads of the biceps, and winds around the surgical neck of the humerus, lying close to the bone. Opposite the bicipital groove it gives off a branch which ascends along the groove to be distributed to the capsule of the shoulder-joint, and it also sends branches to the coraco-brachialis and biceps. It terminates by anastomosing with the posterior circumflex and with the humeral branch of the acromial thoracic.

7. **The Posterior Circumflex Artery.**—The posterior circumflex (**a. circumflexa humeri posterior**) (Fig. 704) arises from the axillary, almost opposite the anterior circumflex, or from a common trunk with that vessel or with the subscapular. More rarely it may arise from the upper part of the brachial artery. It passes backward and outward through the quadrilateral space bounded by the subscapularis above, the teres major below, the long head of the triceps internally, and the humerus externally, and winds around the posterior surface of that bone at the level of its surgical neck. Passing under the deltoid muscle externally, it divides into a number of branches, most of which pass into the muscle to supply it, while some pass to the shoulder-joint. It anastomoses with the acromial branch of the acromial thoracic, with the anterior circumflex, and with the superior profunda branch of the brachial.

THE BRACHIAL ARTERY.

The brachial artery (**a. brachialis**) (Figs. 708, 709) is the continuation of the axillary down the arm. It begins at the lower border of the teres major and terminates a little below the bend of the elbow by dividing into the radial and ulnar arteries. In the upper part of its course the vessel lies along the inner side of the arm, but as it passes downward it inclines somewhat outward, so that in its lower part it is on the anterior surface of the brachium. Its course may be indicated by a line drawn from the junction of the outer and middle thirds of the folds of the axilla to a point midway between the condyles of the humerus.

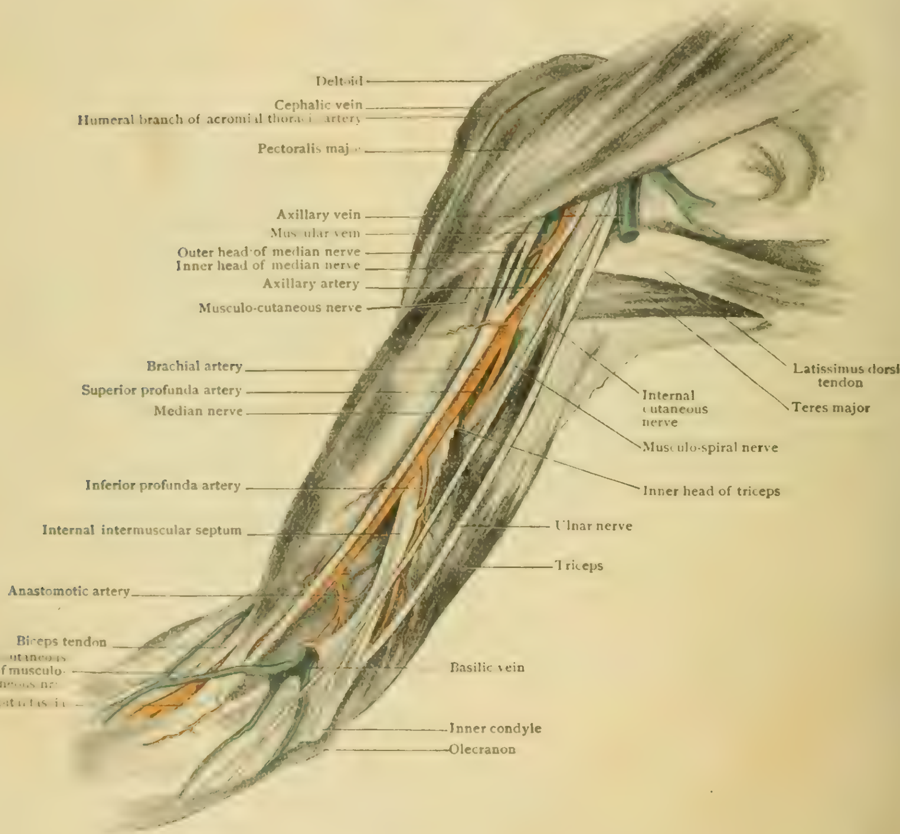
Relations.—*Anteriorly* the brachial artery is covered throughout the greater part of its course by only the deep and superficial fasciæ and the integument. About the middle of its length it is crossed obliquely, from without inward, by the median nerve, and at the bend of the elbow it passes beneath the aponeurotic slip, the so-called bicipital fascia (**lacertus fibrosus**) from the tendon of the biceps, and is separated by it from the median basilic vein. *Posteriorly* it rests in succession, from above downward, upon the long head of the triceps, the inner head of the triceps, the insertion of the coraco-brachialis, and the brachialis anticus. The musculo-spiral nerve and the superior profunda artery pass downward and inward between the vessel and the long head of the triceps. *Externally* to it, above, is the median nerve

and the coraco-brachialis muscle, and, lower down, the biceps and its tendon. *Internally* it is in relation, above, with the ulnar, internal cutaneous, and lesser internal cutaneous nerves, and, in its lower third, with the median nerve. The basilic vein is somewhat superficial to it and to its inner side.

Two venæ comites accompany the artery, lying respectively upon its inner and outer sides, and cross branches pass between the two. It is also accompanied by two lymphatic vessels which have in their course three or four lymphatic nodes, usually of small size.

Branches.—The brachial artery gives off *muscular branches* to the biceps, coraco-brachialis, brachialis anticus, triceps, and pronator radii teres, and a small

FIG. 708.



Brachial artery in relation to nerves of arm.

nutrient artery for the humerus (a. nutriciae humeri) arises either directly from the brachial or from one of its muscular branches or from the inferior profunda. It enters the nutrient foramen upon the inner surface of the shaft of the humerus. In addition, there arise from the brachial (1) the *superior profunda*, (2) the *inferior profunda*, and (3) the *anastomotica magna.*

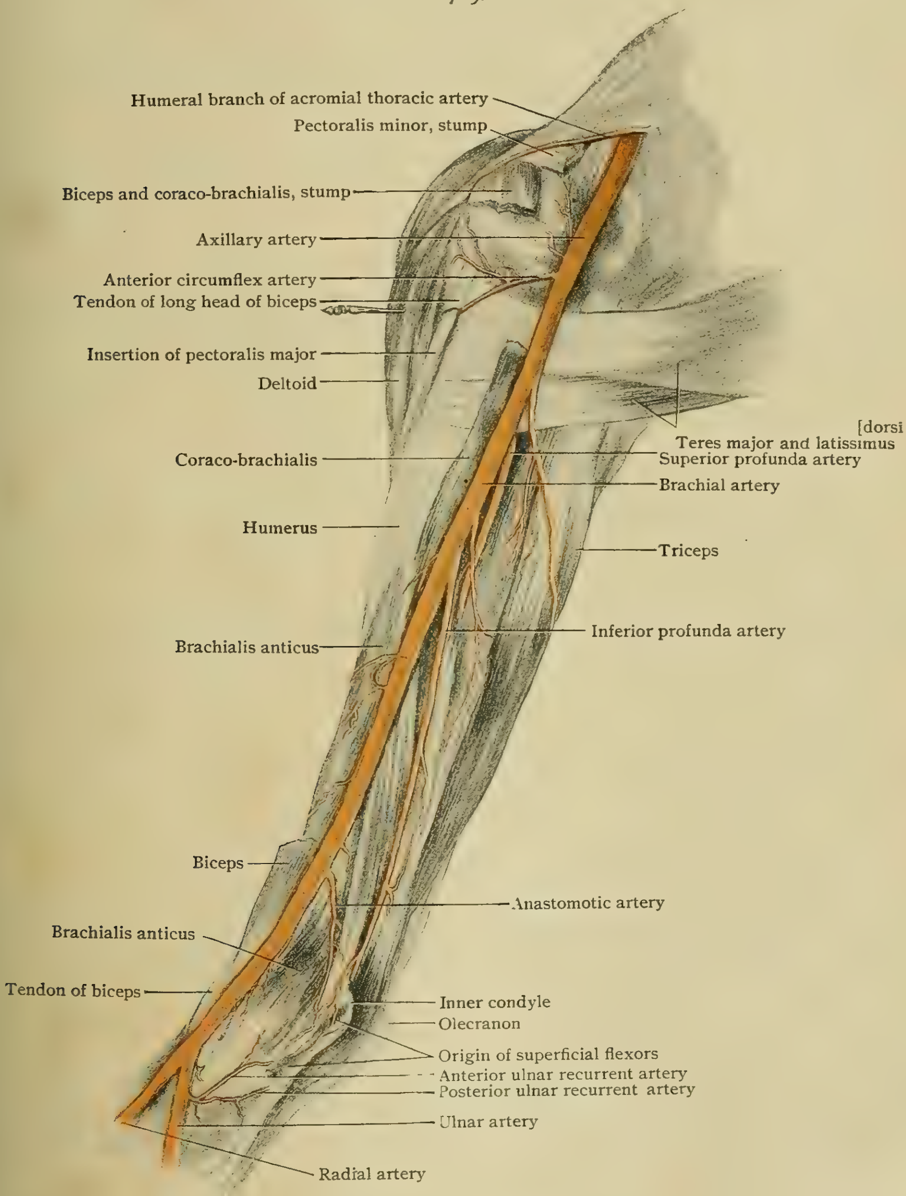
Variations.—The variations which the brachial artery presents are both numerous and important, in that they affect materially the origin of the two terminal branches, the radial and ulnar.

In cases in which there is a well-developed supracondyloid process on the humerus (page 268) the brachial artery accompanies the median nerve behind it, and only passes upon the anterior surface of the arm after it has passed it. In such cases there generally arises from the upper part of the brachial, or even from the axillary, a vessel which descends upon the anterior surface of the arm, lying superficially and sending branches to the biceps and brachialis anticus

muscles. This has been variously termed the *vas aberrans*, the *a. brachialis superficialis*, or the *a. radialis superficialis*, and it appears to be normally present, but much reduced in size and included among the muscular branches.

The majority of the modifications of the brachial artery are due to an extraordinary development of the superficial brachial. Thus it may enlarge and become continuous below with the radial artery, giving rise to a condition usually termed a "high" origin of the radial; more

FIG. 709.



Brachial artery and its branches.

rarely it may unite with the ulnar artery, producing a "high" origin for that vessel; occasionally it gives rise to both the radial and ulnar, the true brachial being continuous below with the common interosseous; or, finally, it may unite with the lower part of the brachial artery proper, the portion of the latter between the origin and anastomosis of the superficial brachial disappearing, so that what is termed a brachial artery is formed, which passes behind instead of in front of the median nerve.

Comparative anatomy and embryology both indicate that the occurrence of a well-developed superficial brachial, continuous below with the radial, is the primary condition, and that the origin of the radial as a terminal branch of the brachial proper is a secondary condition, due to an anastomosis between the lower part of the original superficial stem and the brachial and to the subsequent diminution or partial obliteration of the former above this anastomosis (Fig. 748 *E*).

Another branch, normally present but usually insignificant, which may reach an extraordinary development, is the *a. plicæ cubiti superficialis*. It arises from the lower portion of the brachial and, passing inward and downward beneath the tendon of the biceps, is distributed to the flexor carpi radialis and the palmaris longus. When abnormally developed, it forms what has been termed the *accessory ulnar artery*, and passes down the forearm, immediately beneath the deep fascia and between the two muscles just mentioned, and terminates by anastomosing with the ulnar, or in some cases replaces it and enters into the formation of the palmar arches.

Supernumerary branches accessory to the branches usually present may also occur, and, in addition, the brachial may give rise, in its upper part, to the subscapular and the posterior circumflex, normally branches of the axillary; in its lower part, to the radial recurrent; and, at its bifurcation, to the interosseous artery or to the median, which is usually a branch of the interosseous.

Practical Considerations.—Spontaneous aneurism of the brachial artery is rare, and is usually associated with marked arterio-sclerosis or with cardiac disease. Wounds and traumatic aneurism are common, though lessened in frequency by the protected position of the upper two-thirds of the artery on the inner side of the arm. Aneurism has, however, followed a stab-wound from the outer side, which, after passing through the biceps, involved the vessel. Arterio-venous aneurism just above the bend of the elbow was formerly often met with as a result of the accidental wounding of the artery during phlebotomy of the median basilic vein, parallel with the vessel at that point and separated from it only by the lacertus fibrosus.

The *line* of the artery is from the junction of the anterior and middle thirds of the axilla to the middle of the bend of the elbow when the arm is abducted and the forearm extended and supinated.

The artery in the upper two-thirds of its course may be *compressed* against the inner side of the humerus by pressure directed outward and a very little backward along the internal border of the coraco-brachialis and biceps. This muscular border may be visible, or may be recognized by picking it up between the thumb and finger. The artery may be overlapped by this inner edge of the biceps, especially in muscular subjects. At the middle of the arm, over the insertion of the coraco-brachialis into the flat surface above the beginning of the internal supracondyloid ridge, it may most easily be subjected to compression. In the lower third the pressure must be directed backward, as the humerus—separated from it by the brachialis anticus muscle—then lies behind it.

Ligation of the vessel at its *upper third* is effected through an incision made along the inner border of the muscular ridge of the coraco-brachialis muscle, the fibres of which may with advantage be exposed and identified. Nothing lies between the artery and the muscle except the median nerve. The basilic vein is to the inner side of the vessel and may, before the incision is made, be identified and avoided by compression of the axillary vein above. The ulnar nerve also lies to the inner side. The needle may be passed in either direction.

In ligation at the *middle* of the arm, the limb should be abducted with the elbow slightly flexed, and should be supported by an assistant. If the arm is allowed to rest upon a flat surface, the triceps is pushed upward and may be mistaken for the biceps, and the dissection may bring into view the inferior profunda artery and the ulnar nerve instead of the brachial and the median (Heath). It is well to see and identify the innermost fibres of the biceps. After they are displaced outward, the median nerve (beginning to bear to the inner side) should be separated from the vessel, the sheath opened, the venæ comites (the inner of which is usually the larger) drawn aside, and the needle passed from the nerve. Jacobson calls attention to the fact that this usually easy ligation may be difficult when the artery is concealed by the median nerve at the point at which it is sought, and when its calibre is small and its beat feeble as the result of hemorrhage. The median nerve (from transmitted pulsation), the inferior profunda artery, and even the basilic vein have been mistaken for the brachial.

In ligation at the *lower third*—above the bend of the elbow—the inner edge of the biceps tendon should be distinctly recognized, and the position of the superficial veins, especially the median basilic, should be made apparent by compression above.

The incision should lie just within the edge of the tendon and should be parallel with it, running therefore obliquely from within outward. It will usually be just outside of the median basilic vein. Its centre is about on a level with the transverse fold of the bend of the elbow. The fibres of the bicipital fascia are divided in the line of the skin incision,—*i.e.*, diagonally, as they run downward and inward. The needle may be passed from within outward so as to avoid the median nerve, which, however, is here some distance to the inner side. In all ligations of the brachial, its frequent variations (*vide supra*) should be remembered, and the possibility of the presence of a "vas aberrans" or an "accessory ulnar" should be borne in mind, as should the occasional occurrence of a muscular slip crossing the vessel and derived from the pectoralis major or from one of the humeral muscles.

The *collateral circulation* is carried on after ligation above the superior profunda between the ascending or recurrent branches of that vessel and the circumflex (especially the posterior) and subscapular arteries. After ligation below the origin of the inferior profunda, the circulation is carried on through the anastomosis between the branches of the profunda from above and those of the anastomotic and the recurrents from the radial, ulnar, and posterior interosseous from below. After ligation below the anastomotic, the branches of that vessel, as well as those of the profundæ, carry the blood to the recurrents.

1. **The Superior Profunda Artery.**—The superior profunda (**a. profunda brachii**) (Fig. 709) arises from the upper part of the brachial, on its posterior surface, and is directed downward and outward, between the inner and long heads of the triceps, to reach the posterior surface of the humerus. Accompanied by the musculo-spiral nerve, it curves around to the outer surface of the bone, lying in the musculo-spiral groove, and having arrived at the external supracondylar ridge, it pierces the external intermuscular septum and continues downward between the brachialis anticus and the supinator longus, to terminate by anastomosing in front of the external condyle with the radial recurrent artery.

Branches.—In its course the superior profunda gives off a number of branches, among which may be mentioned:

(*a*) A **deltoid branch** (**ramus deltoideus**), which passes transversely outward to the insertion of the deltoid, and then bends upward in the substance of that muscle.

(*b*) **Muscular branches** to the triceps.

(*c*) A **median collateral branch** (**a. collateralis media**), which passes downward in the substance of the inner head of the triceps to the olecranon process, where it anastomoses with the posterior ulnar recurrent, the posterior interosseous recurrent, and the anastomotica magna.

(*d*) An **articular branch**, which is given off from the lower portion of the artery, just before it pierces the external intermuscular septum, and is distributed to the elbow-joint.

(*e*) **Cutaneous branches**, which accompany the external cutaneous branches of the musculo-spiral nerve.

Variations.—The superior profunda occasionally arises from the axillary artery either directly or in common with the posterior circumflex. That portion of its main stem which traverses the musculo-spiral groove beyond the point where the medial collateral branch is given off is sometimes termed the *radial collateral*, the profunda being regarded as dividing, after a short course, into the two collateral branches. The deltoid artery not infrequently arises directly from the brachial artery or else from the inferior profunda.

2. **The Inferior Profunda Artery.**—The inferior profunda (**a. collateralis ulnaris superior**) (Fig. 709) arises from the inner surface of the brachial, at about the middle of its course. It passes downward and backward, accompanying the ulnar nerve, through the internal intermuscular septum, and then downward along the anterior surface of the inner head of the triceps to the back of the internal condyle, where it terminates by anastomosing with the anastomotica magna and the posterior ulnar recurrent. It gives branches to the triceps and to the brachialis anticus.

3. **The Anastomotica Magna.**—The anastomotica magna (**a. collateralis ulnaris inferior**) (Fig. 709) arises from the inner surface of the brachial artery, about 4 cm. (1½ in.) above its termination. It passes inward over the brachialis anticus and beneath the median nerve, and, piercing the internal intermuscular septum, winds around the inner border of the humerus and passes transversely across its posterior surface, just above the olecranal fossa. It anastomoses with the posterior ulnar recurrent and with both the superior and inferior profunda arteries, and also, by means of a branch given off before it pierces the intermuscular septum, with the anterior ulnar recurrent.

Anastomoses around the Elbow.—The brachial artery forms rich anastomoses around the elbow-joint with both the radial and ulnar arteries by means of its superior and inferior profunda branches and the anastomotica magna, abundant opportunity being thus afforded for a collateral circulation to the forearm after ligation of the brachial. Thus, the superior profunda anastomoses in front of the external condyle of the humerus with the radial recurrent, and its medial collateral branch anastomoses in the neighborhood of the olecranon process with the posterior interosseous and the posterior ulnar recurrents. The inferior profunda also anastomoses with the posterior ulnar recurrent behind the internal condyle, while the anastomotica magna makes connections in front of the internal condyle with the anterior ulnar recurrent; and posteriorly, with the posterior ulnar and the posterior interosseous recurrents.

THE ULNAR ARTERY.

The ulnar artery (**a. ulnaris**) (Figs. 710, 712) is the larger of the two terminal branches of the brachial. It arises just below the bend of the elbow and passes at first distally and inward, in a gentle curve, beneath the muscles which arise from the internal condyle of the humerus, and at the junction of the upper and middle thirds of the forearm assumes a more vertical direction. Arrived at the wrist, it passes over the anterior annular ligament to the radial side of the pisiform bone and then passes across the palmar surface of the hand, forming the *superficial palmar arch* (**arcus volaris superficialis**), whose convexity looks distally, and terminates opposite the second intermetacarpal space by anastomosing with the superficial volar branch of the radial.

For convenience in description, the ulnar artery may be regarded as consisting of three parts: (1) an *antibrachial portion* extending from the origin of the vessel to the upper border of the anterior annular ligament, (2) a *carpal portion* resting upon the annular ligament, and (3) a *palmar portion* in the hand. The course of the lower two-thirds of the antibrachial portion may be represented by a line drawn from the front of the internal condyle of the humerus to a point immediately to the radial side of the pisiform bone, while the course of the upper third may be indicated by a line drawn from the middle of the bend of the elbow to meet the first line at the junction of its upper and middle thirds. The superficial palmar arch is on a level with the thumb when the digit is abducted to a position at right angles to the axis of the hand.

Relations.—The **antibrachial portion** of the ulnar in its upper third is covered by the pronator radii teres, the flexor carpi radialis, the palmaris longus, and the flexor sublimis digitorum, and is crossed obliquely by the median nerve. Behind, it rests upon the tendons of the brachialis anticus and upon the flexor profundus digitorum. In its lower two-thirds it is overlapped above by the flexor carpi ulnaris, but below it lies entirely to the radial side of the tendon of that muscle, and is covered only by the skin and fasciæ. It rests upon the flexor profundus digitorum, and to its radial side is the tendon of the flexor sublimis digitorum, while to its ulnar side it is in close relation with the ulnar nerve, as well as with the tendon of the flexor carpi ulnaris.

In its **carpal portion** it rests upon the anterior surface of the anterior annular ligament, immediately to the radial side of the pisiform bone, and is covered by an expansion from the tendon of the flexor carpi ulnaris.

The **palmar portion**, in the upper part of its course, is covered by the palmaris brevis and rests upon the flexor brevis minimi digiti. The superficial palmar arch, as it passes radialwards, is crossed successively by the palmar branch of the ulnar

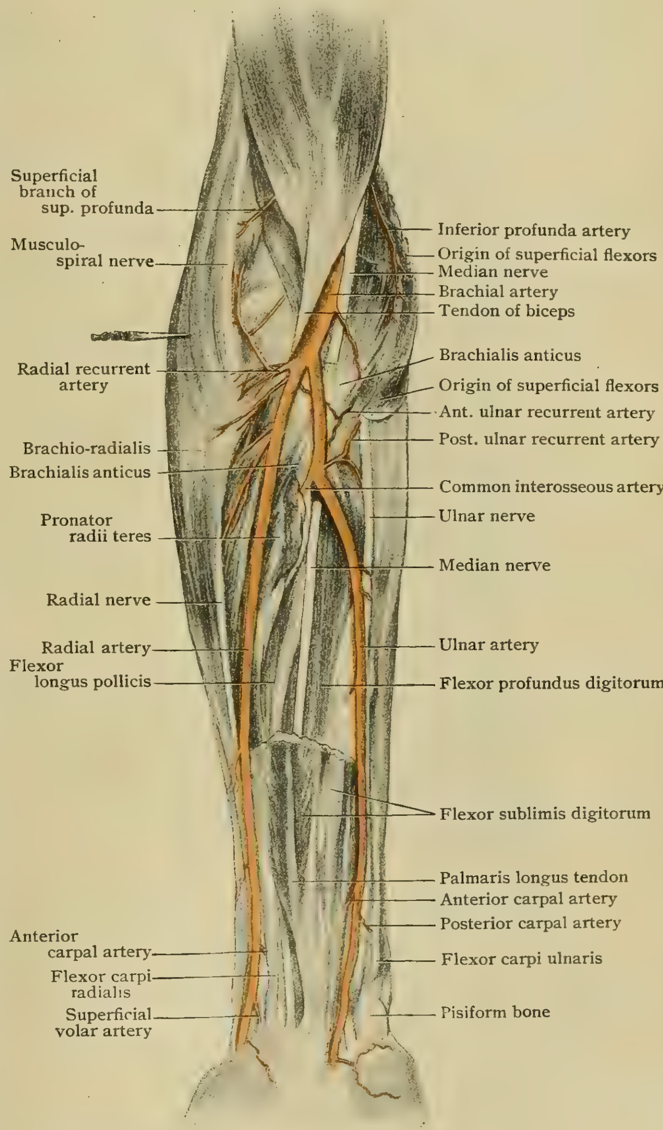
nerve, the palmar fascia, and the palmar branch of the median nerve. It rests upon the digital branches of the ulnar nerve, the long flexor tendons, and the digital branches of the median nerve.

Branches.—From its **antibrachial portion** the ulnar artery gives rise to numerous *muscular branches* supplying the muscles of the forearm, and, in addition, to (1) the *anterior ulnar recurrent*, (2) the *posterior ulnar recurrent*, (3) the *common interosseous*, (4) a *nutrient* branch, (5) the *posterior ulnar carpal*, and (6) the *anterior ulnar carpal*.

From the **carpal portion** arise no branches of considerable size.

From the **palmar portion** arise (7) the *superior* and (8) the *inferior deep palmar* branches and (9) the *digital* branches, and, in addition, *muscular* branches to superficial muscles of the palm and *cutaneous* branches.

FIG. 710.



Radial and ulnar arteries: superficial dissection.

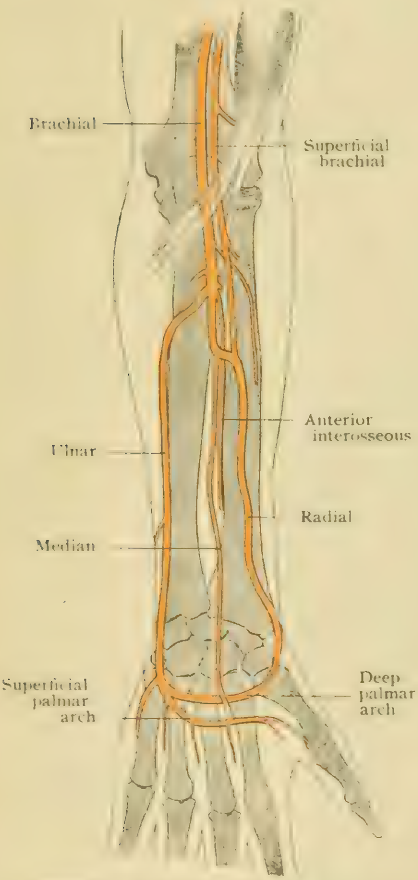
Variations.—From the developmental standpoint the ulnar artery (page 848), although earlier in its appearance than the radial, is, nevertheless, preceded as the principal artery of the forearm by two others. In the most primitive condition the brachial is continued down the forearm, resting upon the interosseous membrane and giving rise at the base of the hand to a leash of digital branches. Later there develops from the brachial a second artery, which passes distally in a plane superficial to the original vessel, accompanying the median nerve through the interval between the flexor sublimis digitorum and the flexor profundus digitorum. This median artery, near the wrist anastomoses with the original one, and the latter then begins to diminish in size and separates from the median above the point of its anastomosis, forming the anterior interosseous artery. In this condition it is the median artery which gives origin to the digital branches. Finally, the ulnar arises as another distinct branch from the brachial and gradually supplants the median, which now appears as a branch of the interosseous known as the a. comes nervi mediani.

As is frequently the case where the development passes through a series of well-marked stages, its arrest may occur at any one of these, and consequently an anomaly may occur in which the ulnar artery is represented only by some muscular branches, its place being taken by

a persistent median or interosseous artery,—a condition of which indications are to be seen in the participation of the interosseous or median artery in the formation of the superficial palmar arch (page 785). An interesting condition in which indications are clearly retained of all the stages which the forearm arteries pass through in their evolution is shown in Fig. 711. An artery which is the superficial brachial, and which arose from the axillary, descends the arm parallel to the brachial proper and terminates by becoming the radial. A distinct ulnar has developed and the anterior interosseous has acquired its typical arrangement, but there is a well-developed median artery which sends a strong branch across to the radial and terminates by anastomosing with the superficial palmar branch of the ulnar to form the superficial palmar arch.

Another variation may occur in the form of a "high origin" of the ulnar artery, a condition which results from the anastomosis of the superficial brachial artery (page 774) with the ulnar. In such cases the ulnar frequently passes down the forearm in a much more superficial position than usual, passing over, instead of under, the muscles arising from the internal condyle. Such a superficial course may also be followed when the artery has a normal origin, and occasionally it passes to the ulnar border of the forearm between the palmaris longus and the flexor sublimis digitorum.

FIG. 711.



Variation of arteries of left arm, showing retention of developmental conditions.

Practical Considerations.—The ulnar artery may be ligated for wound or for aneurism—of which it is rarely the subject—either (1) about the middle of the forearm or (2) just above the wrist.

1. With the forearm supinated, an incision on the line indicated (*vide supra*) through the skin and the thin deep fascia should expose either a white line—the tendinous edge of the flexor carpi ulnaris—which is not always present (Treves), or a yellow (fatty) interspace (Farabeuf) between that muscle and the flexor sublimis digitorum. It is best marked at the lower part of the wound. If more than one white line should be present, the one sought for would be nearer the ulnar margin of the limb. At the bottom of the interspace thus identified, which runs obliquely inward towards the ulna, the artery will be found lying on the flexor profundus digitorum, with the ulnar nerve to its inner side. It is often overlapped by the inner deep edge of the flexor sublimis, so that that muscle must be lifted up and drawn outward before the vessel can be fully exposed. In separating the muscles care must be taken not to go beyond the vessel and nerve—pushing them to the radial side—and open up the interspace between the flexor carpi ulnaris and the flexor profundus. The space between the flexor sublimis and the palmaris longus lies to the outer side of the proper space, but is much more shallow and even less well marked.

2. Forcibly extend the hand so as to bring into prominence the fleshy swell of the flexor sublimis muscle and tendons, just to the ulnar side of the palmaris longus (page 620). The incision, beginning about one inch above the flexure of the wrist, should be made in the groove to the inner side of this prominence, and is immediately in line with the pisiform bone. After the deep fascia is divided the tendon of the flexor carpi ulnaris is seen and, after it is relaxed by flexion of the wrist, is drawn a little inward, when the artery will be found still lying upon the flexor profundus and bound to it by a definite layer of fascia, which must be carefully divided (Treves). The ulnar nerve lies in close proximity to the vessel on the ulnar side.

The venæ comites of the ulnar are closely attached to it, but may be included in the ligature without danger, as the other venous channels of the forearm are amply sufficient to carry on the circulation.

The *collateral circulation* is maintained by means of the free anastomosis between the branches of the radial and ulnar, those of the interosseous vessels, and those of the carpal and palmar arches.

1. **The Anterior Ulnar Recurrent Artery.**—The anterior ulnar recurrent (**a. recurrens ulnaris anterior**) (Fig. 712) arises from the upper part of the ulnar artery, frequently in common with the posterior recurrent. It is usually a rather slender branch, and is directed upward in the groove between the brachialis anticus and the pronator radii teres towards the internal condyle, over which it terminates in branches which anastomose with the inferior profunda and anastomotica magna of the brachial. It gives off branches to the neighboring muscles and a branch to the anterior inner portion of the capsular ligament of the elbow-joint.

2. **The Posterior Ulnar Recurrent Artery.**—The posterior ulnar recurrent (**a. recurrens ulnaris posterior**) (Fig. 712) arises either immediately below the anterior recurrent or by a common trunk with it. It is usually considerably larger than the anterior recurrent, and passes at first almost horizontally inward and backward between the flexor sublimis and the flexor profundus digitorum, and then bends upward along the side of the ulnar nerve between the two heads of the flexor carpi ulnaris. It terminates upon the posterior surface of the internal condyle of the humerus in branches which anastomose with the posterior branch of the inferior profunda and with the anastomotica magna of the brachial.

It gives branches to the adjacent muscles, to the skin, and to the posterior internal portion of the capsule of the elbow-joint.

3. **The Common Interosseous Artery.**—The common interosseous (**a. interossea communis**) (Fig: 710) arises from the outer and back part of the ulnar artery, a short distance below the posterior ulnar recurrent. It is a short, stout trunk which passes downward and outward and, having reached the upper border of the interosseous ligament, divides into the anterior and posterior interosseous arteries.

Variations.—In cases in which a superficial brachial artery (page 774) exists, the true brachial may be directly continuous below with the common interosseous, the radial and ulnar arteries arising by the bifurcation of the superficial brachial. Such cases form what are usually termed "high" origins of the common interosseous; and, since the superficial brachial may arise from the axillary, owing to the anastomosis with it of the aberrant branch of that artery, the common interosseous may also appear to arise from the axillary.

In cases of high origin of the radial the common interosseous may arise from that vessel and give origin to the recurrent ulnar branches, and it may also give rise to these branches when it has a normal origin. When it has a high origin, it may give off both the radial and ulnar recurrent branches.

a. **The Anterior Interosseous Artery.**—The anterior interosseous (**a. interossea volaris**) (Fig. 712) descends from the point of bifurcation of the common interosseous artery, along the anterior surface of the interosseous membrane, between the adjacent edges of the flexor profundus digitorum and the flexor longus pollicis, and divides at the upper border of the pronator quadratus into an anterior and a posterior terminal branch (Fig. 715).

Branches.—In addition to **muscular branches** to the adjacent muscles and to the extensor muscles of the thumb,—the latter perforating the interosseous membrane to reach their destinations,—the anterior interosseous artery gives off a number of more or less important branches.

(*aa*) The **median artery** (**a. comes nervi mediani**) arises from the anterior surface of the anterior interosseous, immediately below the origin of that vessel. It passes forward to join the median nerve, which it accompanies down the arm, and in whose substance it is frequently embedded. It continues its course with the nerve beneath the anterior annular ligament, and, when well developed, may terminate by anastomosing directly with the superficial palmar arch.

(*bb*) A **nutrient branch** is usually given off to the radius and occasionally also to the ulna.

(*c*) The **anterior terminal branch** passes either over or beneath the pronator quadratus, and terminates usually by anastomosing with branches of the anterior radial and ulnar carpal and with the palmar recurrent arteries. Occasionally it anastomoses directly with the superficial palmar arch.

(*d*) The **posterior terminal branch** is larger than the anterior. It perforates the interosseous membrane, anastomoses with the posterior interrosseous artery, and terminates in branches which anastomose with the posterior radial and ulnar carpals to form the dorsal carpal net-work.

Variations.—The anterior interosseous artery may arise from the radial, and it may form anastomoses below with the radial or with both the radial and ulnar. The relations which it sometimes possesses with the superficial palmar arch will be considered later,

The median artery is occasionally of considerable size and frequently arises from the common interosseous. Its relations to the superficial palmar arch will also be considered later (page 785).

b. **The Posterior Interosseous Artery.**—The posterior interosseous (**a. interossea dorsalis**) (Fig. 715) passes backward between the radius and ulna, above the concave upper margin of the interrosseous membrane. It thus reaches the posterior portion of the forearm and turns abruptly downward between the superficial and deep layers of the extensor muscles, and breaks up at the wrist into branches which anastomose with the posterior radial and ulnar carpals and with the posterior terminal branch of the anterior interosseous, assisting in the formation of the dorsal carpal net-work.

Just as it reaches the posterior surface of the forearm it gives off a **posterior interosseous recurrent branch** (**a. interossea recurrens**), which ascends between the anconeus and the supinator brevis to the posterior surface of the external condyle of the humerus, where it anastomoses with the superior profunda and the anastomotica magna. In its course down the arm the posterior interosseous gives branches to the extensor muscles, and, through the dorsal carpal net-work, it takes part in the supply of the articulations of the wrist and carpus.

4. **The Ulnar Nutrient Artery.**—The nutrient branch for the ulna arises from the upper third of the ulnar artery or from one of its muscular branches, or from the anterior interosseous. It enters the nutrient foramen situated upon the anterior surface of the bone, near its outer border.

5. **The Posterior Ulnar Carpal Artery.**—The posterior ulnar carpal (**ramus carpeus dorsalis**) (Fig. 715) is small. It arises from the inner surface of the ulnar artery, just above the pisiform bone, and winds inward beneath the tendon of the flexor carpi ulnaris to the back of the carpus, where it anastomoses with the posterior radial carpal and the posterior interosseous to form the dorsal carpal net-work.

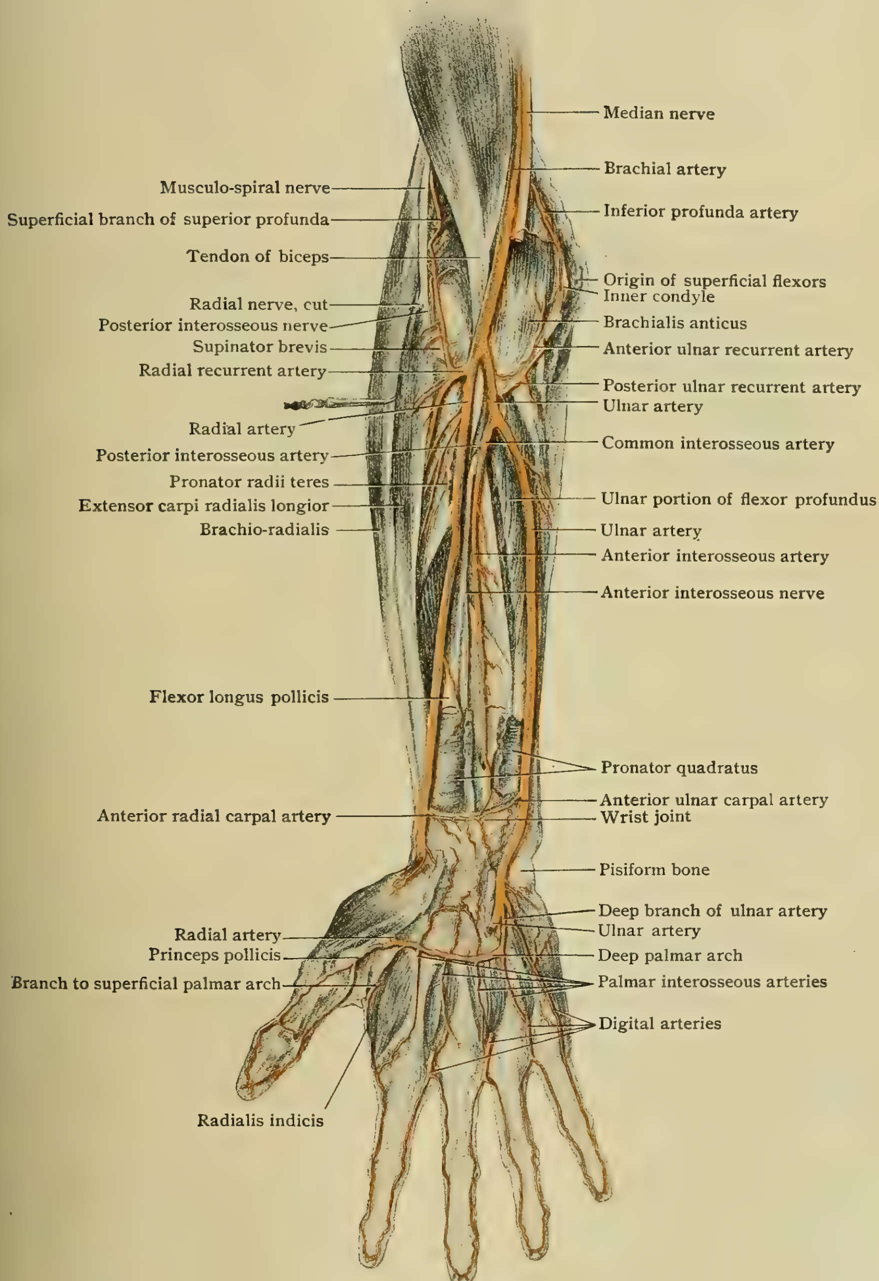
6. **The Anterior Ulnar Carpal Artery.**—The anterior ulnar carpal (**ramus carpeus volaris**) (Fig. 712) is also small. It arises from the ulnar artery, just above the upper border of the anterior annular ligament, and passes outward upon the carpal ligaments and beneath the long flexor tendons to anastomose with the anterior radial carpal and anterior interosseous to form the anterior carpal net-work.

7 and 8. **The Deep Palmar Arteries.**—The deep palmar branches (**rami volares profundi**) (Fig. 712) are given off from the ulnar artery, just after it has entered the palm. The **superior branch** arises just after the ulnar artery has passed the pisiform bone, and passes dorsally in the interval between the flexor brevis minimi digiti and the abductor minimi digiti. It then perforates the opponens minimi digiti, and terminates by inosculating with the deep palmar arch.

The **inferior branch** arises just as the ulnar artery is bending to pass transversely across the palm. It passes dorsally between the flexor brevis minimi digiti and the long flexor tendon for the little finger, and terminates by inosculating with the deep palmar arch, near the superior branch.

Frequently one or other of these branches, more usually the superior one, is lacking, and only one communication between the ulnar and the deep palmar arch exists. In their passage dorsally, both arteries give off branches to the adjacent muscles.

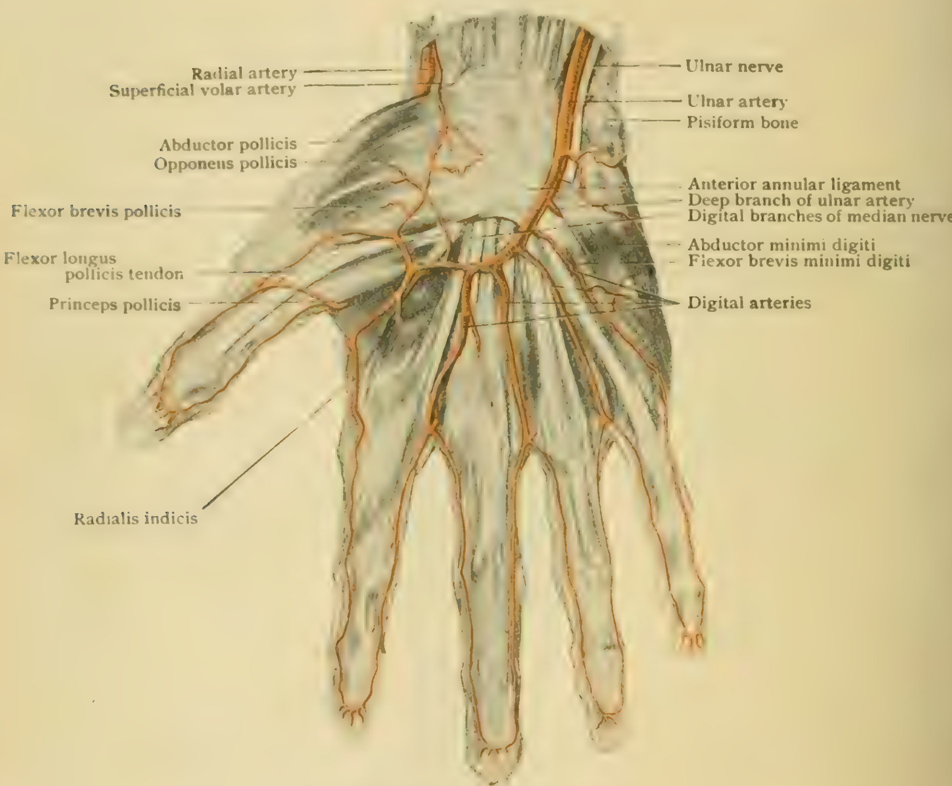
FIG. 712.



Deep arteries of right forearm and hand; flexor surface.

9. **The Digital Arteries.**—The digital branches (**aa. digitales volares communes**) arise from the portion of the ulnar artery which passes transversely across the palm of the hand and is termed the **superficial palmar arch** (**arcus volaris superficialis**). They are four in number; the first of the four, starting from the ulnar border of the hand, passes obliquely downward and inward across the hypothenar muscles and continues distally along the ulnar border of the little finger. The

FIG. 713.



Superficial palmar arch and its branches.

remaining three pass downward in the second, third, and fourth intermetacarpal spaces resting upon the lumbrical muscles, and, just before reaching the clefts of the fingers, each receives the corresponding palmar interosseous artery and then divides into two branches, the **collateral digital branches** (**aa. digitales volares propriae**), which extend distally upon the adjacent sides of the neighboring digits. These collateral branches make numerous transverse anastomoses with one another, especially in the neighborhood of the interphalangeal joints, and terminate in fine branches which supply the bulb of the finger and the bed of the nail.

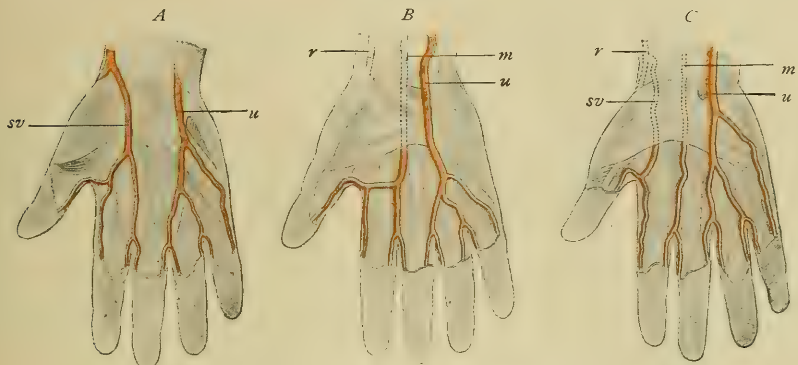
Variations.—The variations of the digital arteries depend principally (1) upon their proportional development with regard to the palmar interosseous vessels from the deep palmar arch, and (2) upon variations in the mode of formation of the superficial palmar arch.

The palmar interosseous branches of the radial anastomose with the digitals just before the division of the latter into their collateral branches, and if the interosseæ are strongly developed, the digitals are apt to be of small calibre, and may be so much reduced in size that the collaterals of one or more of them may be regarded as continuations of the corresponding palmar interosseæ. Conversely, although normally the supply for the radial side of the index-finger and the thumb is from the deep palmar arch, yet occasionally it is derived from the superficial arch, the princeps pollicis and the radialis indicis, the branches from the deep palmar arch, being much reduced in size.

The variations in the formation of the superficial palmar arch are frequent and numerous, and may be grouped in two classes: (1) those in which additional branches from the forearm participate in the formation of the arch or replace the radial in its composition, and (2) those in which there is no true arch, the arteries which should participate in its formation, and in some cases additional ones also, failing to anastomose and each giving rise independently to a certain number of digital branches. To the first of these classes belong the cases in which the median or anterior interosseous artery anastomoses directly with the arch formed by the superficial volar and the ulnar, and also those in which the superficial volar fails to reach the ulnar, the arch being formed by the union of the latter vessel with the median or the anterior interosseous. And, finally, the arch may be formed by the ulnar artery alone, no direct communication taking place between it and the arteries mentioned.

In the second class of cases—that in which there is no true arch—the ulnar and the superficial volar, on reaching the palm, divide in a somewhat fan-like manner to give rise to the digital branches. The superficial volar may contribute the fourth digital, as well as the vessels to the thumb and radial side of the index (Fig. 714, *A*), or it may be limited to the latter vessels, all four normal digitals being derived from the ulnar. With the absence of the arch there may be associated an extra development of the median artery, which continues distally into the palm as the fourth digital vessel, the remaining digitals and the radialis indicis and princeps pollicis being supplied by the ulnar and radial respectively (*C*). Or, finally, with the extra development of the median there is associated an absence, more or less complete, of the superficial volar, the median giving off the branches to the radial digit as well as the fourth digital (*B*).

FIG. 714.



Variations of palmar arteries replacing superficial arch. (*Jaschtschinski*).

THE RADIAL ARTERY.

The radial artery (**a. radialis**) (Figs. 710, 712) is the smaller of the two terminal branches of the brachial, whose course it continues downward through the forearm. It arises at the bend of the elbow and passes down the outer border of the forearm to the level of the styloid process of the radius, where it bends outward, curving around the external lateral ligament of the wrist. It then extends downward over the posterior surface of the trapezium until it reaches the interval between the first and second metacarpal bones, and here it again changes its direction and passes forward into the palmar surface of the hand, across which it is continued inward over the anterior surfaces of the second, third, and fourth metacarpals, forming what is termed the **deep palmar arch** (**arcus volaris profundus**). It terminates opposite the proximal part of the fourth metacarpal interspace by anastomosing with the deep palmar branch of the ulnar.

In accordance with its position with reference to the bony axis of the forearm and hand, the radial artery may be regarded as consisting of three parts. In its first or *antibrachial portion* it is preaxial in position, in the second or *carpal portion* it is postaxial, and in the third or *palmar portion* it is again preaxial.

Relations.—In its **antibrachial portion** the course of the artery may be indicated by a line drawn from a point midway between the two condyles of the humerus to a point about 1 cm. internal to the styloid process of the radius. In its upper half it is overlapped in front by the inner border of the brachio-radialis (supinator longus) muscle, but lower down it is covered only by the deep and superficial fasciæ

and the skin. Posteriorly it rests successively, from above downward, upon the tendon of the biceps, the supinator brevis, the pronator radii teres, the radial portion of the flexor sublimis digitorum, the flexor longus pollicis, the outer border of the pronator quadratus, and the anterior surface of the lower end of the radius. Internally it is in contact with the pronator radii teres in its upper third, and throughout the rest of its course with the outer border of the flexor carpi radialis. Externally it is in relation throughout its entire length with the brachio-radialis, and in the middle third of its course it is in contact with the radial nerve. Two venæ comites accompany the artery, lying to its inner and outer sides.

In its **carpal portion** the radial artery rests at first upon the external lateral ligament of the wrist and then upon the posterior surface of the trapezium. It passes beneath, successively, the tendons of the extensor ossis metacarpi pollicis, the extensor brevis pollicis, and the extensor longus pollicis, being covered in the interval between the last two and to the ulnar side of the extensor longus pollicis only by the skin and fasciæ, in which are some branches of the radial nerve and tributaries of the radial vein.

In its **palmar portion**, as it passes forward through the proximal portion of the first intermetacarpal space, the artery lies between the two heads of the first dorsal interosseous muscle. It then bends inward beneath the oblique head of the adductor pollicis, and, either penetrating that muscle or passing between it and the transverse head of the same muscle, is continued ulnarward beneath the tendons of the long flexors, resting upon the bases of the metacarpal bones and upon the interosseous muscles.

Branches.—From its **antibrachial portion** the radial artery gives off numerous *muscular branches* to the muscles on the radial side of the forearm, and, in addition, gives origin to (1) the *radial recurrent*, (2) the *anterior radial carpal*, and (3) the *superficial volar*.

From its **carpal portion** it gives rise to (4) the *posterior radial carpal*, (5) the *dorsalis pollicis*, and (6) the *dorsalis indicis*.

From its **palmar portion** its branches are (7) the *princeps pollicis*, (8) the *palmar interosseous* (of which there are three), and (9) the *recurrent carpals*.

Variations.—The high origin of the radial has already been considered in discussing the variations of the brachial artery (page 774). It is the last of the forearm arteries to be developed in the comparative series, and its relations with the arterial supply to the hand is due to secondary anastomoses which it makes with vessels originally present, whereby it has come to give origin to many branches formed before its appearance. Thus the dorsalis indicis and the dorsalis pollicis are primarily digital branches from the dorsal interosseous artery of the first intermetacarpal space, and this artery arose from the posterior carpal arch and has become a portion of the radial by the anastomosis of that artery with the arch. Similarly the portion of the radial which passes forward between the first and second metacarpals to join the deep palmar arch is primarily the first posterior perforating vessel, which has secondarily become the deep palmar apparent continuation of the radial, and has brought that vessel into direct continuity with the arch and given it the branches which originally arose from that vessel.

The secondary anastomoses of the original radial with pre-existing vessels have, however, become well established, and variations of the radial, other than its high origin, are rather uncommon. It has been observed to terminate in an anastomosis with an enlarged posterior carpal arch, or in the lower part of the forearm by anastomosis with the anterior interosseous artery. Its absence below the point where the radial recurrent is given off has also been observed, its territory in such cases being supplied by the interosseous.

Occasionally it passes to the dorsal surface of the arm much higher up than usual, and in such cases the superficial volar branch also arises at a much higher level than usual and passes downward along the line usually occupied by the radial artery. It is an exceedingly slender vessel, and, being felt at the place where the pulse is usually examined, may give rise to erroneous conclusions as to the quality of that phenomenon.

Practical Considerations.—The radial artery, like the ulnar, is the subject of idiopathic aneurism only with great rarity, but a stab-wound may result in a traumatic aneurism, or may necessitate immediate ligation for control of hemorrhage. The vessel may be tied in any part of its course.

1. At the *upper third* of its antibrachial portion it is reached through an incision made on the line described (*vide supra*), which, after the deep fascia is opened up, should disclose the interspace between the brachio-radialis and the pronator radii

teres. This is often indicated by a yellowish (cellulo-fatty) line. The fibres of the former muscle are almost parallel with the long axis of the forearm and overlie the artery ; those of the latter are oblique and lie close to the inner side of the vessel. The nerve is so far external that it is not likely to be seen. The artery, with its venæ comites, lies on the supinator brevis.

2. At the *middle* of the forearm the incision is made on the same line. The same relations exist, except that there the nerve is usually very near to the outer side of the artery, which now lies on the tendon of insertion of the pronator radii teres.

As the brachio-radialis is not very wide at this part (especially if the artery is sought for at the lower end of the middle third), it is very easy to expose the outer instead of the inner border of the muscle, in which case the muscle is apt to be drawn inward, and when the depths of the wound are opened up the radial nerve is reached. This is the common error of beginners.

The tendon of the brachio-radialis, as a rule, first makes its appearance at the outer border of the muscle, so that if this tendinous edge is exposed the operator will know that he has laid bare the wrong side of the muscle. The inner border of the latter remains muscular, until it ends somewhat abruptly in the tendon (Treves).

3. At the *lower third* the incision should be made midway between the tendon of the brachio-radialis and that of the flexor carpi radialis, the latter of which may be made prominent by strongly extending the hand. The vessel is very superficial, and is disclosed as soon as the thin fascia is divided. The nerve has left the vessel altogether (at a level of from three inches above the wrist to the middle of the forearm) and has passed under the brachio-radialis tendon to the dorsum of the hand.

4. In the triangular fossa between the lower end of the radius and the root of the thumb (*tabatière anatomique*), bounded externally by the tendon of the extensor longus pollicis, internally by the tendons of the extensor brevis pollicis and the extensor ossis metacarpi pollicis, and superiorly by the inferior margin of the posterior annular ligament (Fig. 716), the radial artery may occasionally require ligation on account of wound or of aneurism. An incision one inch and a half long should be made obliquely across the fossa, observing to avoid one of the chief radicles of the radial vein, which lies in the superficial fascia immediately in the course of the wound. After opening the fascia, and displacing some loose adipose tissue, the artery will be reached at the bottom of the depression between the tendons of the thumb. It is desirable to avoid opening the sheaths of the tendons or the joint between the scaphoid and trapezium ; these bones together with the base of the first metacarpal form the floor of the space.

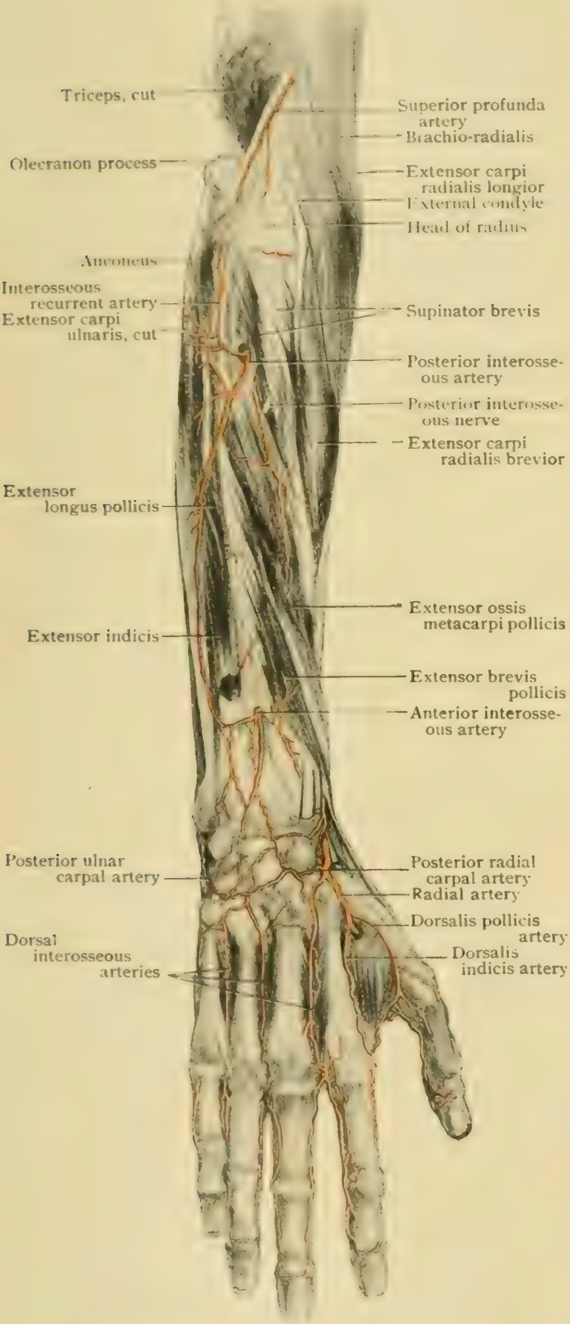
The *collateral circulation* after ligation of the radial is carried on as after ligation of the ulnar, *q.v.*

Wounds of a palmar or carpal arch are apt to be troublesome on account of the occasional difficulty in finding and securing both ends of the divided vessel, and because of the very free anastomosis between the palmar and carpal arches and the interosseous vessels, which leads to recurrent hemorrhage, even after ligation of both radial and ulnar. Compression over the wound, firm bandaging from the finger-tips to the axilla, and elevation of the limb, are, for these reasons, the methods usually first employed, and if applied thoroughly will generally be effectual. Ligation of the brachial is indicated when these have failed, on account of the necessity for getting above the interosseous anastomotic supply (*vide supra*).

1. **The Radial Recurrent Artery.**—The radial recurrent (a. recurrens radialis) (Fig. 712) arises from the outer surface of the radial, shortly below its origin. It is at first directed downward upon the surface of the supinator brevis, but quickly bends upward towards the external condyle of the humerus, passing between the radial and posterior interosseous nerves and lying beneath the supinator longus. It gives numerous branches to the supinator longus and brevis and to the extensor carpi radialis longior and the extensor carpi radialis brevior, and terminates at the external condyle by anastomosing with the superior profunda from the brachial artery.

2. The Anterior Radial Carpal Artery.—The anterior radial carpal (**ramus carpea volaris**) (Fig. 712) is usually a small branch which arises from near the lower end of the antibrachial portion of the radial. It passes inward beneath the flexor tendons at about the lower border of the pronator quadratus, and breaks up into a number of small branches which anastomose with branches from the anterior ulnar carpal, the anterior interosseous, and the recurrent carpals to form an anterior carpal net-work. From this net-work branches pass to the wrist and to the carpal articulations.

Fig. 715



Arteries of extensor surface of forearm and hand.

3. The Superficial Volar Artery.—The superficial volar (**ramus volaris superficialis**) (Fig. 713) arises usually just where the radial bends outward and backward to reach the posterior surface of the wrist. It is usually rather slender, although variable in size, and is directed downward, passing either over, through, or beneath the adductor pollicis, supplying that and the other muscles of the thenar eminence, and terminates usually by anastomosing with the superficial palmar branch of the ulnar to form the superficial palmar arch.

Variations.—The superficial volar is somewhat variable both as to size, origin, and mode of termination. It occasionally arises high up upon the radial, and in such cases that vessel passes to the posterior surface of the arm at a much higher level than usual. Not infrequently it takes no part in the formation of the superficial palmar arch, and may terminate in the muscles of the thenar eminence, the digital branches being all given off by the superficial palmar branch of the ulnar; or, on the contrary, appearing as a well-developed stem, it may divide distally into from one to four digital arteries, the remaining ones arising directly from the superficial palmar branch of the ulnar or partly from that and partly from the median artery (page 784).

4. The Posterior Radial Carpal Artery.—The posterior radial carpal (**ramus carpeus dorsalis**) (Fig. 715) is a small branch which is given off from the radial just as that vessel passes beneath the tendon of the extensor ossis metacarpi pollicis. It passes horizontally inward beneath

the tendons of the extensor carpi radialis longior and the extensor carpi radialis brevior, and anastomoses, either directly or by means of a number of small branches, with the posterior ulnar carpal, forming a *posterior carpal arch* or net-work.

Branches.—From the posterior carpal arch or net-work a longitudinal stem passes distally in each of the three inner intermetacarpal spaces. These are the **dorsal interosseous arteries** (**aa. metacarpeae dorsales**). At the upper extremity of its intermetacarpal space each interosseous artery receives the corresponding perforating branch from the palmar interosseous artery, and when it reaches the interval between the bases of the proximal phalanges, it divides into two branches, which run forward upon the inner and outer surfaces respectively of the proximal phalanges of the adjacent digits and terminate in small branches upon these phalanges.

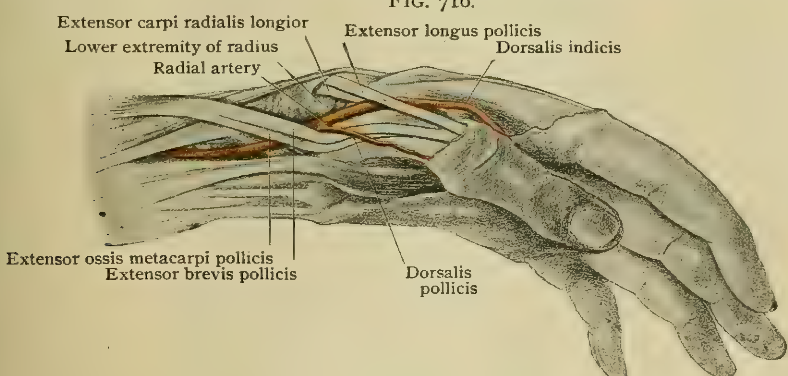
A slender branch, which arises either directly from the dorsal carpal arch or from the interosseous artery of the fourth intermetacarpal space, passes along the inner border of the metacarpal and proximal phalanx of the little finger. It terminates upon the proximal phalanx of its digit.

Variations.—Considerable variation occurs in the size of the dorsal interosseous arteries. That which traverses the fourth intermetacarpal space is sometimes wanting, while that of the second space is sometimes of considerable size and may arise directly from the radial artery. Occasionally each artery undergoes a sudden increase of calibre at the point where it is joined by the perforating branch from the deep palmar arch, and may appear to be the continuation of the perforating branch. Where it divides into its two terminal branches, each interosseous gives off an inferior perforating branch, which passes forward to communicate with the corresponding palmar digital artery ; but these perforating branches are frequently wanting, with the exception of that given off from the artery of the second intermetacarpal space.

5. **The Dorsalis Pollicis Artery.**—The dorsalis pollicis (Fig. 715) is a slender artery which arises from the radial just before it passes beneath the tendon of the extensor longus pollicis. It passes distally along the dorsal surface of the first metacarpal and terminates upon the dorsum of the first phalanx of the thumb.

6. **The Dorsalis Indicis Artery.**—The dorsalis indicis (Fig. 715) arises from the radial just as it passes between the two heads of the first dorsal interosseous muscle to enter the palm of the hand. It passes distally along the radial border of the second metacarpal, resting upon the first dorsal interosseous muscle, and terminates

FIG. 716.



Dissection showing relation of radial artery to extensor tendons in "snuff box."

upon the first phalanx of the index-finger. It frequently gives off a small branch which passes along the inner border of the metacarpal and first phalanx of the thumb.

Variations.—The dorsalis indicis, together with the carpal portion of the radial distal to the point at which the posterior radial carpal is given off, represents the dorsal interosseous artery of the first intermetacarpal space. The branch to the inner border of the thumb represents one of the terminal branches of that artery, and frequently arises directly from the radial opposite the main stem of the dorsalis indicis.

7. **The Princeps Pollicis Artery.**—The a. princeps pollicis (Fig. 717) arises from the radial just as it emerges from between the two heads of the first dorsal interosseous muscle and is bending horizontally inward to form the deep palmar arch. The artery passes directly distally, resting upon the palmar surface of the first dorsal interosseous muscle and being covered by the adductor pollicis. While still beneath the

caput obliquum of the adductor, the vessel frequently divides into two branches, one of which is continued distally along the radial border of the index-finger, forming what has been termed the **a. radialis indicis** (a. volaris indicis radialis), while the other extends along the first metacarpal and, passing between the two heads of the adductor, divides beneath the tendon of the flexor longus pollicis into two branches, which pass distally along the palmar surface of the thumb, one along the inner and the other along the outer border, anastomosing with the branches of the dorsalis pollicis.

Variations.—The a. princeps pollicis is in reality the palmar interosseous artery of the first intermetacarpal space, and, when developed as described, corresponds in the arrangement of its branches with the dorsalis indicis, together with the dorsalis pollicis. Frequently, however, the branch to the radial border of the index-finger is lacking, or, on the other hand, it may be well developed and arise directly from the deep palmar arch, or sometimes both it and the princeps pollicis are derived from the superficial palmar arch (page 784).

8. **The Palmar Interosseous Arteries.**—The palmar interosseous arteries (**aa. metacarpeae volares**) are three in number, and arise from the deep palmar arch as

FIG. 717.

Semidiagrammatic reconstruction of right hand, viewed from palm, showing relations of arteries to surface and to bones; vessels on dorsal surface are represented in outline.

it crosses the second, third, and fourth intermetacarpal spaces. Each artery passes distally in its intermetacarpal space, resting upon the interosseous muscles, and

nates by anastomosing with the corresponding digital artery from the superficial palmar arch just before the digital divides into its two terminal branches. Immediately at its origin each palmar interosseous gives off a **perforating branch** (**ramus perforans**) which passes dorsally between the adjacent metacarpals to communicate directly with the corresponding dorsal interosseous artery.

Variations.—The palmar interosseous arteries vary considerably in size, according as the digital branches from the superficial palmar arch are well or poorly developed (page 784). When the ulnar palmar digital is small, an extra branch may arise from the deep palmar arch, passing along the ulnar border of the little finger.

9. **The Palmar Recurrent Arteries.**—The palmar recurrent arteries (Fig. 717) are two or three small branches which arise from the concave surface of the deep palmar arch and pass proximally over the carpus to anastomose with the terminal branches of the anterior interosseous and of the anterior radial and ulnar carpal arteries. By the anastomosis of these various arteries there is formed upon the anterior surface of the carpus a net-work, the *rete carpale volare*, from which branches are distributed to the wrist and to the carpal articulations.

The Collateral Circulation in the Forearm.—The brachial artery, after being ligated, will convey blood to the forearm arteries by means of its superior and inferior profunda branches and by the anastomotica magna, which form a rich anastomosis at the elbow-joint with the radial recurrent, the anterior and posterior ulnar recurrent, and the posterior interosseous recurrent. The collateral circulation in the parts supplied by the ulnar and radial arteries, after ligation of one or other of these vessels, will be carried on by means of the direct anastomoses between the two arteries in the superficial and deep palmar arches and also by way of the anterior and posterior carpal net-works. To the former of these net-works the radial artery sends contributions from its posterior carpal branch and the ulnar from its posterior carpal and anterior and posterior interosseous branches, while to the latter the radial sends its anterior carpal branch and the ulnar its anterior carpal and anterior interosseous branches.

THE THORACIC AORTA.

The thoracic aorta (**aorta thoracalis**) (Fig. 718) is the continuation of the descending limb of the aortic arch, and begins upon the left side of the body of the fourth thoracic vertebra. It passes downward through the thorax in the posterior mediastinum and terminates below at the diaphragm, behind which it passes to become continuous with the abdominal aorta. In the upper part of its course it lies a little to the left of the median line, but it tends slightly to the right as it descends, and eventually occupies the median line just before it reaches the diaphragm.

Relations.—*Anteriorly* it is in relation with the left bronchus and the root of the left lung in its upper part, and it is crossed very obliquely by the œsophagus, which separates it from the pericardium and the posterior surface of the left auricle of the heart. *Posteriorly* it rests upon the bodies of the eight lower thoracic vertebræ, or rather throughout the greater part of its extent upon the anterior common ligament of the thoracic vertebræ, and at about the level of the fifth vertebra has passing obliquely upward behind it the thoracic duct and, at the level of the eighth vertebra, the vena hemi-azygos.

Upon the *right side* are, above, the œsophagus and lower down the right pleura. The thoracic duct passes upward upon its right side and slightly behind it as far as the fifth thoracic vertebra, and the vena azygos also lies upon its right side, but on a plane slightly posterior to it. On the *left side* are the left lung and pleura above, and below, the œsophagus, while the vena hemi-azygos also lies upon its left side, but on a somewhat posterior plane.

Branches.—The branches which arise from the thoracic aorta may be divided into two groups, according as they are distributed to the thoracic viscera or to the parietes. The visceral branches are (1) the *bronchial*, (2) the *œsophageal*, and (3) the *mediastinal*. The parietal branches are (4) the *aortic intercostal* arteries, and (5) the *diaphragmatic* branches.

Variations. The passage of the thoracic aorta down the right side of the vertebral column in the upper part of its course and the origin from it of the right subclavian artery have already been discussed in connection with the variations of the aortic arch (page 724). It was there pointed out that both these abnormalities depend upon the more or less perfect persistence of the lower portion of the right primitive aortic arch. Not infrequently a modification of this condition is to be seen in the existence of a small branch arising from the upper part of the thoracic aorta and passing obliquely upward and to the right behind the œsophagus. This is the **arteria aberrans**, and it is to be regarded as a persistence in a rudimentary condition of the distal portion of the right primitive aortic arch. It is regarded by some authors as a normal branch of the thoracic aorta, but it is somewhat inconstant in its occurrence. Occasionally it anastomoses with the first or second intercostal branches of the superior intercostal artery (page 765).

1. **The Bronchial Arteries.**—The bronchial arteries (**aa. bronchiales**) (Fig. 718) are somewhat variable in number; while three are usually described, they may be reduced to two or increased to four. They arise from the upper portion of the thoracic aorta and pass to the right and left bronchi, and are continued along these to supply the tissue of the lungs. The **right bronchial artery**, which very frequently arises from the first right aortic intercostal, passes to the right in front of the œsophagus and applies itself to the posterior surface of the right bronchus, along which it passes to the lung. In its course it gives off minute branches to the œsophagus, bronchus, and pericardium, and to the lymphatic nodes in its neighborhood.

The **left bronchial arteries**, which are usually two in number, apply themselves at once to the posterior surface of the left bronchus as it passes in front of the aorta and are continued along this to the lung. They give off small branches to the œsophagus and to neighboring lymphatic nodes. The upper of the two vessels frequently arises by a common stem with the right bronchial, and may be the only one that is present.

2. **The Œsophageal Arteries.**—The œsophageal branches (**aa. œsophageae**) (Fig. 718) of the thoracic aorta are also variable in number, forming a series of four or sometimes five or six small vessels which arise in succession from above downward from the anterior surface of the aorta. After a short but somewhat tortuous course, they reach the œsophagus, in the wall of which they branch to form a net-work which receives branches from the bronchial arteries, from the inferior thyroid above and the gastric artery below.

3. **The Mediastinal Arteries.**—The mediastinal arteries (**rami pericardiaci**) are a number of small vessels which arise from the anterior surface of the thoracic aorta and are distributed to the mediastinal lymph-nodes and the posterior surface of the pericardium.

4. **The Aortic Intercostal Arteries.**—The aortic intercostals (**aa. intercostales**) (Fig. 718) supplying the tissues of the lower intercostal spaces, are usually nine in number on each side, while a tenth, sometimes termed the **subcostal artery**, runs along the lower border of the last rib, supplying the upper part of the abdominal wall. The arteries arise in pairs from the posterior surface of the thoracic aorta and pass outward over the bodies of the vertebræ to the intercostal spaces, those of the right side being, for the most part, somewhat longer than those of the left, owing to the position of the thoracic aorta to the left of the vertebral column throughout the greater portion of its length. Arrived at the intercostal space, each artery passes obliquely outward and upward across the space towards the angle of the rib next above, resting upon the internal intercostal fascia, and covered by pleura. It then pierces the intercostal fascia and, as far as the angle of the rib, runs between the fascia and the external intercostal muscle. On reaching the angle of the rib the artery passes beneath the internal intercostal muscle and is continued around the thoracic wall in the subcostal groove of the rib, and between the two intercostal muscles, to terminate usually by inosculating in front with the upper of the two anterior intercostal arteries given off by the internal mammary or the musculo-phrenic to each intercostal space. The arteries which pass to the tenth and eleventh intercostal spaces continue onward beyond the extremities of their corresponding ribs, and, passing between the oblique muscles of the abdomen, anastomose with the deep epigastric artery. The same arrangement occurs in the case of each of the tenth aortic intercostal (subcostal) arteries. These, however, throughout that portion of

their course in which they are in relation to the twelfth ribs, rest upon the quadratus lumborum muscles, beneath the transversalis fascia, and at the outer border of that muscle pass beneath the fibres of the transversalis abdominis, and, more laterally, perforating the internal oblique, come to lie between that muscle and the external oblique.

Relations.—In the first portion of their course, while passing over the bodies of the vertebræ, the right aortic intercostals are crossed by the thoracic duct and by the vena azygos, and the upper ones are also crossed by the œsophagus. Those of the left side are crossed by the vena hemiazygos, and both sets are covered by the pleura. Opposite the heads of the ribs they are crossed by the ganglionated cord of the sympathetic nervous system, the lower ones also by the splanchnic nerves, and in their course through the intercostal spaces they are in relation to the intercostal veins and nerves, each artery lying below its corresponding vein and above the nerve, but on a plane slightly posterior to both. The arteries of the upper spaces lie at first below the corresponding nerves, but as they approach the lower borders of their ribs they cross the nerves obliquely, and throughout the greater part of their course possess the relation described.

Branches.—Each artery gives off small branches to the bodies of the vertebræ and to the pleura, and throughout its course through the intercostal space numerous.

(*a*) **Muscular branches,** which supply the intercostal muscles, the serratus magnus, and the pectorales major and minor, anastomosing with the thoracic branches from the axillary artery. The vessels of the lower spaces and the subcostal also supply the upper portions of the abdominal muscles, the subcostal anastomosing with branches of the uppermost lumbar artery and with the ascending branch of the superficial circumflex iliac; the lower vessels also give off numerous branches to the diaphragm which anastomose with the phrenic arteries from the abdominal aorta. Some of the muscular branches which arise from the vessels of the third, fourth, and fifth spaces send branches to the mammary gland, assisting the perforating branches of the internal mammary and the long thoracic branch of the axillary in the supply of that structure. These **intercostal mammary branches** (**rami mammarii laterales**) may become greatly enlarged during lactation, and may give rise to considerable hemorrhage in the operation for removal of the gland.

In addition, each aortic intercostal gives off a dorsal, a lateral cutaneous, and a collateral branch.

(*b*) The **dorsal branch** (**ramus posterior**) arises from each artery, just as it enters its intercostal space, and passes directly backward, in company with the posterior division of the corresponding spinal nerve, between the necks of the adjacent ribs and internal to the superior costo-transverse ligament. Having reached the vertebral groove, it divides into a *spinal* and a *muscular* branch. The former (**ramus spinalis**) passes through the intervertebral foramen in company with the root of the spinal nerve, and, within the spinal canal, gives off branches to the body of the vertebra and its neural arches and to the dura mater, and also branches which pass to the spinal cord and anastomose with the anterior and posterior spinal arteries. The *muscular branch* (**ramus muscularis**) continues posteriorly in the direction of the main stem of the vessel and divides into an external and an internal branch which pass between the principal masses of the dorsal musculature, supplying these and terminating in branches to the integument of the back.

(*c*) The **lateral cutaneous branch** (**ramus cutaneus lateralis**) arises at about the axillary line and perforates the external intercostal muscle in company with the lateral cutaneous branch of the corresponding intercostal nerve. It is distributed with the nerve to the integument of the lateral portions of the thorax, also supplying the serratus magnus and the pectoral muscles and anastomosing with the perforating branches of the internal mammary and with the thoracic branches of the axillary artery.

(*d*) The **collateral branch** arises as the intercostal approaches the angle of its rib. It passes obliquely outward and downward to the upper border of the rib next below, along which it runs to terminate by anastomosing with the lower of the two anterior intercostal branches given off by the internal mammary or the musculo-phrenic to each intercostal space. The collateral branches of the three lower intercostals are small and inconstant and, when present, terminate in the abdominal wall.

Variations.—The intercostal arteries of the first and second spaces usually arise from the superior intercostal branch of the subclavian, but occasionally the artery of the second space, and more rarely that of the first, may arise from the thoracic aorta. Or, conversely, the arteries of the third and fourth intercostal spaces, as well as those of the first and second, may arise from the superior intercostal, the aortic intercostals being correspondingly reduced in number.

Occasionally the second intercostal is formed by a branch from the first aortic intercostal which runs upward to the second space over the neck of the third rib, and a similar condition may be met with in the lower arteries, two or more intercostal spaces being supplied from a common stem. Finally, the right and left arteries of one or all of the pairs may arise from a common stem, springing from the posterior median line of the aorta.

Practical considerations of the thoracic aorta are discussed with those of the aortic arch on page 726.

THE ABDOMINAL AORTA.

The abdominal aorta is the continuation below the diaphragm of the thoracic aorta. It may be said to begin, therefore, at the lower border of the twelfth thoracic vertebra, and passes downward upon the bodies of the four upper lumbar vertebræ lying almost in the median line. It is usually described as terminating opposite the fourth lumbar vertebra by dividing into the right and left common iliac arteries, although it is really continued onward beyond that point as a relatively feeble vessel which is termed the *middle sacral artery*. It seems advisable, however, to adhere to the classic definitions of the artery, and to regard the middle sacral, for purposes of description, as one of its branches.

Relations.—*Posteriorly*, the abdominal aorta rests upon the anterior common ligament of the four upper lumbar vertebræ and crosses the left lumbar veins. *Anteriorly*, in its uppermost part, it is invested by the sympathetic solar plexus, from which branches pass downward along the vessel, forming the aortic plexus. A little lower it is crossed by the splenic vein, the pancreas, the left renal vein, and the third portion of the duodenum, and still lower it is in relation with the coils of the small intestine, from which, however, it is separated by the peritoneum. Upon a more anterior plane there are, above, the left lobe of the liver, and the stomach and transverse colon. *To the right*, it is in contact, in its upper part, with the thoracic duct and the receptaculum chyli, which lie partly covered by it, and with the right crus of the diaphragm, which separates it from the inferior vena cava ; lower down it is in direct contact with the vena cava. *To the left*, is the left crus of the diaphragm and the fourth portion of the duodenum above, while below it is separated by the peritoneum from coils of the small intestine, and has running alongside the left spermatic (ovarian) artery and vein, and still more laterally the left ureter.

Branches.—The branches of the abdominal aorta, like those of the thoracic, may be divided into two sets, visceral and parietal.

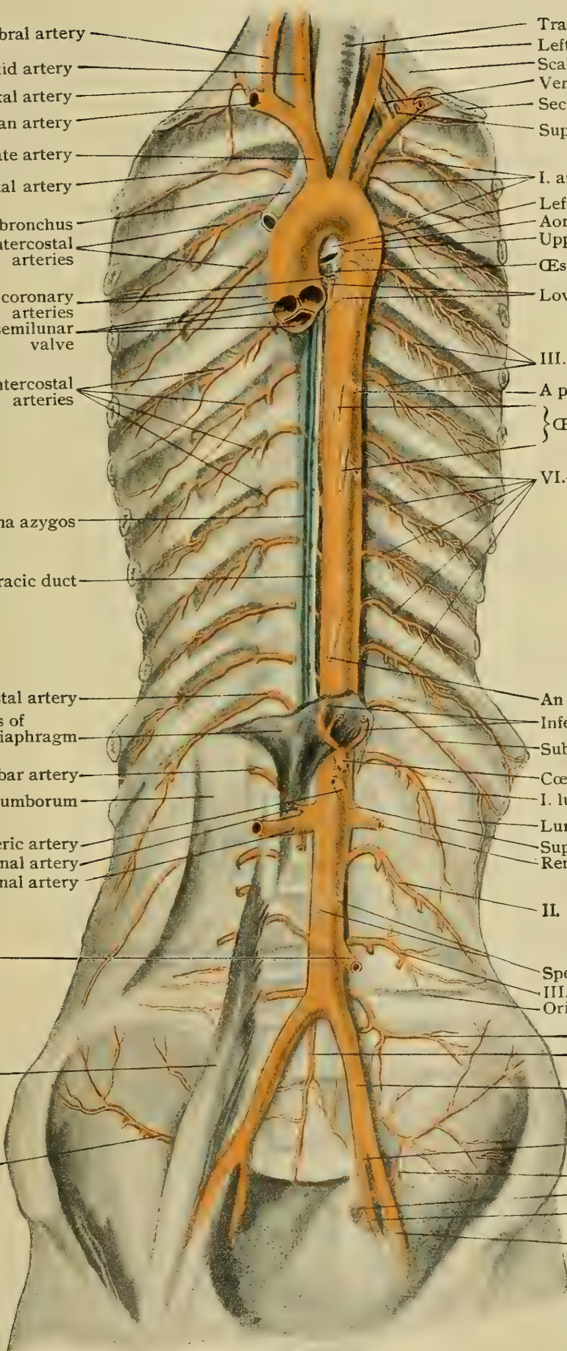
The **visceral branches** are (1) the *cœliac axis*, (2) the *superior mesenteric*, and (3) the *inferior mesenteric* artery. These are median unpaired branches which arise from the anterior surface of the aorta; in addition, there are a number of paired visceral branches: (4) the *inferior phrenic*, (5) the *suprarenal*, (6) the *renal*, and (7) the *spermatic* or *ovarian* arteries.

The **parietal branches** are (8) the *lumbar* arteries, of which there are four pairs, (9) the *middle sacral*, and (10) the *common iliac* arteries. With the exception of the middle sacral, the parietal branches are all paired.

Considered in the *order of their origin* from the aorta, the branches are arranged thus: (1) The *inferior phrenics*, (2) the *cœliac axis*, (3) the *suprarenals*, (4) the *superior mesenteric*, (5) the *first pair of lumbar* arteries, (6) the *renals*, (7) the *spermatics* or *ovarians*, (8) the *second pair of lumbars*, (9) the *inferior mesenteric*, (10 and 11) the *third* and *fourth pairs of lumbars*, (12) the *middle sacral*, and (13) the *common iliacs*.

Variations of the abdominal aorta are not common. In cases in which the aortic arch bends to the right, the abdominal aorta may lie somewhat to the right of the median line, and it has been observed to pass downward upon the right of the inferior vena cava. Variations also occur in the level at which the aorta bifurcates into the common iliacs. In the majority of cases the bifurcation is opposite the middle of the fourth lumbar vertebra, but it is not infrequently lower, taking place opposite the lower half of that vertebra, opposite the succeeding intervertebral disc, or, in rare cases, opposite the upper portion of the fifth vertebra. Bifurcation at a higher level than usual is less frequent, but it has been observed as high as opposite the intervertebral disc between the third and fourth vertebræ, and, in very rare cases, the artery has been found to divide as high as the second lumbar vertebra.

FIG. 718.



Aorta and its branches; ten intercostal arteries are present, first supplying second space; on right side internal intercostal muscles are in position, on left they have been removed.

Although the abdominal aortic stem is very constant in its relations, considerable variation occurs in the origin of its branches. Most of these will be considered in connection with the description of the branches concerned, but it may be noted here that very frequently a number of small branches, terminating in the neighboring organs or connective tissue and lymph-nodes, arise from the abdominal aorta, in addition to the branches which have already been named. These small branches are rather inconstant, and may arise from either the anterior surface of the aorta, in which case they are unpaired vessels, or in pairs from its sides.

Their existence seems to indicate the occurrence of a primitively strictly segmental arrangement of the branches of the abdominal aorta, and a type-condition has been supposed to occur in which the aorta gives off, opposite each segmental interval that it passes, three pairs of vessels, which arrange themselves in three distinct sets (Fig. 719). One set arises from the anterior surface of the aorta, and is usually reduced, either by fusion or by the degeneration of one or other of each pair, to a single unpaired vessel for each segment; a second set arises from the sides of the aorta and, like the first set, is distributed to the abdominal viscera; and a third set arises from the posterior surface of the aorta and is distributed to the abdominal parietes.

FIG. 719.

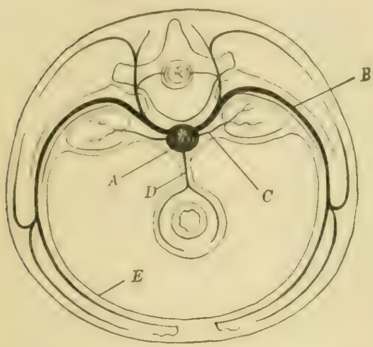


Diagram showing fundamental arrangement of branches of abdominal aorta. *A*, main body-trunk (aorta); *B*, somatic branch to body-walls; *C*, paired visceral branches; *D*, unpaired visceral branch; *E*, peritoneum.

Of the unpaired set of vessels, only three persist until adult life, becoming the cœliac axis and the superior and inferior mesenteric arteries, the position occupied by these vessels in the adult being due to a downward migration which they undergo, the cœliac axis representing the ventral visceral branch of the fourth thoracic or possibly a higher segment, the superior mesenteric that of the seventh thoracic, and the inferior mesenteric that of the twelfth thoracic. The paired visceral branches are developed mainly in connection with the embryonic kidney, and on the replacement of this by the adult organ the majority of them disappear, the suprarenal, renal, and spermatic arteries and certain inconstant branches which are lost in the neighboring connective tissue representing them in the adult. Of the parietal paired set, the four pairs of lumbar arteries correspond to the four upper lumbar segments, while the common iliacs are the branches of the fifth lumbar segment. The lumbar arteries are evidently serially homologous with the thoracic intercostals and present many similarities to the lower members of that series, but the common iliacs are peculiar in that they give rise to branches which pass to the pelvic viscera, a condition which may be explained by the fact that the paired visceral branches of the third lumbar segment unite with them and are represented by the hypogastric artery and its branches.

Practical Considerations.—The abdominal aorta is the subject of *aneurism* much more rarely than is the thoracic aorta, because of the relatively less powerful cardiac impulse which reaches it. The sac is most often situated in the neighborhood of the cœliac axis because (*a*) in this region the artery has lost the support afforded by the tendinous arch of the diaphragm, which produces a constriction in its walls at each ventricular systole; (*b*) it rather suddenly contracts about one and a half inches below this level (after having given off a number of large branches), so that the intervening portion is somewhat fusiform or pouched (Agnew); (*c*) the pressure on this aortic segment is increased by the sudden alteration in the direction of the blood-current caused by the presence of these branches (the inferior phrenics, the cœliac axis, the suprarenals, superior mesenteric, etc.); and (*d*) the walls at this point are said to be intrinsically weak, often giving way (Woolsey) during injections of the cadaver. The aneurism may occupy any aspect of the vessel, but is more commonly on the anterior wall, which receives less support. As it enlarges it will cause some or all of the following symptoms:

1. *Tumor* in the epigastric or hypochondriac region (usually the left because there is less resistance from surrounding organs and because the artery inclines in that direction), having the characteristic bruit and expansile pulsation, commonly capable of being outlined by palpation or grasped (distinguishing it from a "throbbing aorta"), and unchanged as to pulsation and impulse when the patient is put in the knee-elbow position (eliminating growths of the left lobe of the liver, the pylorus, or the pancreas, in which the tumor falls forward—*i.e*, downward—and the impulse lessens or disappears) (Osler). 2. *Dyspnœa* from interference with the descent of the diaphragm. 3. *Dysphagia* from pressure on the œsophageal opening. 4. *Dys*

pepsia and *vomiting* directly from pressure upon the stomach, and indirectly from involvement of the solar plexus. 5. *Jaundice* from compression of the common duct and duodenum. 6. *Polyuria* followed by *albuminuria* and *hæmaturia* or *anuria* from pressure on the renal nerves. 7. *Œdema* of the legs and feet from pressure on the ascending cava. If the tumor enlarges posteriorly there is apt to be also: 8. *Pain* in the buttocks, thighs, and loins from pressure on the lumbar nerves, and in the back from pressure on the solar plexus and splanchnics, or from erosion of the vertebra; and rarely there may be: 9. *Weakness* or *paralysis* of the lower extremities from involvement of the cord. As a rule, the pain, distress, and disability are not so great in abdominal as in thoracic aneurism, because of the greater mobility of the abdominal contents, which can be much more easily displaced than those of the middle or posterior mediastinum and with consequences not so directly threatening life.

Abdominal aneurisms rupture into the retroperitoneal space, the peritoneal cavity, the intestines (most often the duodenum), or—after ulcerating through the diaphragm—into the pleura.

Compression of the abdominal aorta may be effected by special tourniquets, the intestines being first well emptied and then got out of the way, as far as possible, by rolling the patient on the right side before applying the pad, between which and the skin a soft sponge should be interposed. The pad is placed a little to the left of the umbilicus, or, better—as the aorta may be median in position—directly over the pulsation of the vessel. Macewen has effectively controlled the abdominal aorta by throwing the weight of the body on the aorta through the closed right hand placed a little to the left of the middle line, the knuckle of the index-finger just touching the upper border of the umbilicus. With the left hand the arrest of the blood-current is ascertained by feeling the femoral at the brim of the pelvis. Only enough weight to arrest the femoral pulse is required. If the patient vomits or coughs, the pressure must be increased, lest the hand be lifted from the aorta by the abdominal muscles.

Of course these methods would be applicable only to aneurisms situated near the bifurcation. Compression has cured at least one such case. They have, however, been applied in iliac and common femoral aneurism and to control hemorrhage during inter-ilio-abdominal or hip-joint amputation.

Ligation of the abdominal aorta has been done in about a dozen cases with uniformly fatal results. The ligature has been applied between the bifurcation and the origin of the inferior mesenteric artery—one and a half to two inches higher. A median incision with its centre at the umbilicus is made, the peritoneal cavity opened, and the intestines displaced. The layer of peritoneum over the artery is carefully divided —or scratched through—and the vessel isolated, avoiding the sympathetic fibres connecting the aortic plexus (lying above the origin of the inferior mesenteric) with the hypogastric plexus (lying between the common iliacs) (Astley Cooper, Jacobson). The dense areolar tissue surrounding the vessel is penetrated and the aneurism needle is passed through it from right to left to avoid injury to the vena cava. The extraperitoneal operation closely resembles that for ligation of the common iliac (page 808).

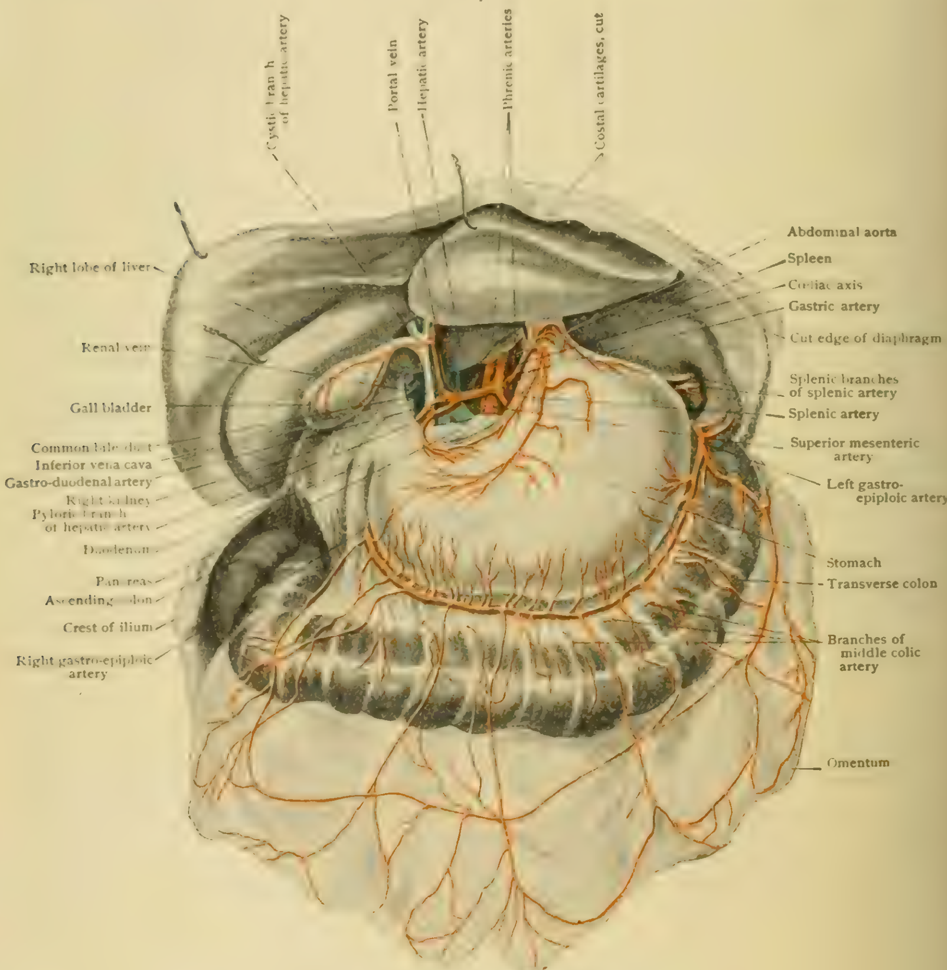
THE VISCERAL BRANCHES.

1. **The Cœliac Axis.**—The cœliac axis (**a. coeliaca**) (Figs. 720, 721) arises from the anterior surface of the abdominal aorta, a short distance below the aortic opening of the diaphragm, and is a short, stout trunk from 1–1.5 cm. in length, which projects forward above the upper border of the pancreas. It terminates by dividing simultaneously into (1) the *gastric*, (2) *hepatic*, and (3) *splenic arteries*.

Variations.—The cœliac axis may be wanting, the three branches to which normally it gives origin arising independently from the aorta. Occasionally it gives rise to but two terminal branches, usually the hepatic and splenic, although more rarely they may be the gastric and splenic; or, while dividing into three terminal branches, these may be the gastric, hepatic, and a common stem from the two inferior phrenics; the gastric, splenic, and the right suprarenal; or the gastric, splenic, and the right gastro-epiploic. It may also give rise to additional branches, such as one or both of the inferior phrenics, a gastro-duodenal, the superior mesenteric, the colica media, or the pancreatica magna, this last being normally a branch of the splenic artery.

(*a*) **The Gastric Artery.**—The gastric artery (**a. gastrica sinistra**) (Fig. 720) is the smallest of the three branches given off from the cœliac axis. In the first portion of its course it passes to the left and slightly upward, across the left crus of the diaphragm, lying behind the posterior layer of the lesser sac of peritoneum. It reaches the lesser curvature of the stomach near the opening of the œsophagus into that viscus, where the upper part of the posterior wall of the lesser sac of peritoneum passes over upon the stomach to become continuous with the posterior layer of the lesser

FIG. 720.



Cœliac axis and its branches.

(gastro-hepatic) omentum. It then curves forward, downward, and to the right along the lesser curvature of the stomach, lying between the two layers of the lesser omentum, frequently dividing into two parallel stems in this portion of its course, and terminates near the pyloric end of the stomach by anastomosing with the pyloric branch of the hepatic artery.

Branches.—Just at the point where the gastric artery reaches the stomach it gives off—

(*aa*) Œsophageal branches (**rami œsophagei**) which pass upward to supply the lower portion of the œsophagus, anastomosing with the œsophageal branches of the thoracic aorta and with branches of the inferior phrenic arteries. Throughout the entire length of its course along the lesser curvature of the stomach the gastric artery gives rise to—

(*bb*) **Gastric branches** which pass downward over both surfaces of the stomach, anastomosing with the short gastric branches from the splenic artery and with the gastric branches which pass upward from the gastro-epiploic arch which passes along the greater curvature of the stomach. Some of the branches which arise from the more proximal portion of the artery and ramify over the cardiac portion of the stomach are frequently described as the *cardiac branches.*

(*cc*) A small **hepatic branch** passes upward between the two layers of the lesser omentum towards the left end of the transverse fissure of the liver, where it anastomoses with the left branch of the hepatic artery.

Variations.—The gastric artery occasionally arises directly from the abdominal aorta, in which case it may give rise to one or both of the inferior phrenic arteries. Its hepatic branch is not infrequently enlarged, and then constitutes the main stem of the left branch of the hepatic artery, which thus seems to arise from the gastric

(*b*) **The Hepatic Artery.**—In the first portion of its course the hepatic artery (**a. hepatica**) (Figs. 720, 721) passes from left to right and slightly forward, over the right crus of the diaphragm, lying beneath the posterior wall of the lesser sac of peritoneum. Where this passes over into the posterior layer of the lesser (gastro-hepatic) omentum towards the right, the artery bends upward and ascends, in the free edge of the lesser omentum, towards the transverse fissure of the liver, where it divides into two terminal branches.

Relations.—In the first portion of its course the hepatic artery rests below upon the upper border of the head of the pancreas and is in contact above with the lower surface of the Spigelian lobe of the liver, upon which it frequently makes a distinct impression. It lies at first upon a plane posterior to the portal vein, but later it crosses the left surface of the vein and comes to lie in front of it. In its course upward in the free edge of the lesser omentum the artery lies anteriorly to the portal vein and upon the left side of the common bile-duct.

Branches.—As the hepatic artery passes between the two layers of the lesser omentum it gives origin to two branches, the pyloric and the gastro-duodenal.

(*aa*) The **pyloric branch** (**a gastrica dextra**) is the smaller of the two. It descends to the pyloric end of the stomach and then, bending to the left, runs along the lesser curvature of the stomach, between the two layers of the lesser omentum, and terminates by anastomosing with the gastric artery. It gives branches to either side of the pyloric extremity of the stomach and, like the gastric artery, is frequently represented by two parallel vessels.

(*bb*) The **gastro-duodenal** (**a. gastroduodenalis**), the larger branch, descends behind the first portion of the duodenum and terminates at its lower border by dividing into two branches, the superior pancreatico-duodenal and the right gastro-epiploic.

(*aaa*) The *superior pancreatico-duodenal branch* (**a pancreaticoduodenalis superior**) descends to the head of the pancreas, upon the surface of which it anastomoses with branches of the inferior pancreatico-duodenal branch of the superior mesenteric artery. It sends branches into the substance of the gland and to the walls of the duodenum.

(*bbb*) The *right gastro-epiploic artery* (**a. gastroepiploica dextra**) passes to the left along the greater curvature of the stomach, between the folds of the greater omentum, and inosculates with the left gastro-epiploic branch of the splenic artery. It sends branches upward upon both surfaces of the stomach, which anastomose with branches from the gastric artery and from the pyloric branch of the hepatic, and other branches pass downward into the greater omentum (epiploön).

(*cc*) The **terminal branches** are two in number and pass the one to the right and the other to the left lobe of the liver. The *right branch* (**ramus dexter**) passes towards the right extremity of the transverse fissure of the liver, its course lying either in front of the hepatic and cystic ducts or between these two structures. At the extremity of the fissure it divides into a number of branches which enter the substance of the right lobe of the liver. As it passes across the hepatic duct it gives off a **cystic branch** (**a cystica**) which runs downward and forward along the cystic duct to the gall-bladder, whose walls it supplies, also giving some small branches to the liver. The *left branch* (**ramus sinister**) is directed towards the left end of the transverse fissure, and, after giving off one or two branches which enter the substance of the Spigelian lobe, terminates by dividing into a number of branches which enter the left lobe of the liver.

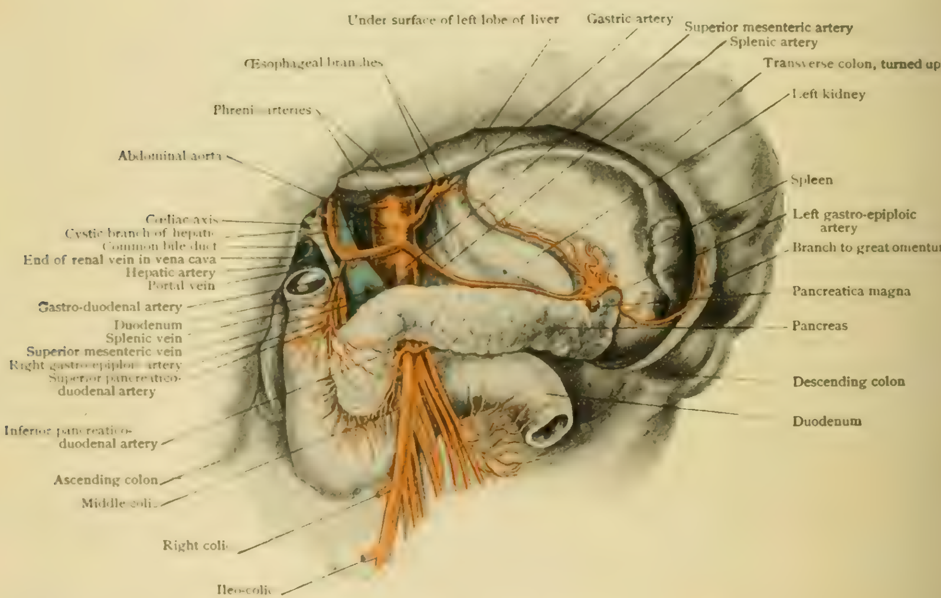
Variations.—Variations of the hepatic artery are exceedingly frequent. The artery itself may arise directly from the aorta instead of from the cœliac axis, or, by the enlargement of its anastomoses and the diminution of the normal main stem, it may appear to be a branch of the

gastric or more frequently of the superior mesenteric artery. It has also been described as arising from the right renal artery. Further, by the enlargement of anastomoses, associated with a persistence of the normal main stem, accessory hepatic arteries from the gastric or superior mesenteric, or both may be present, and an accessory stem may arise from the aorta.

Great variation occurs in the point at which the artery divides into its two terminal branches. This division may occur as low down as the origin of the gastro-duodenal branch, so that in its course up the free edge of the lesser omentum the artery may be represented by two parallel stems which pass respectively to the right and left lobes of the liver. Indeed, not only may there be a precocious division into the two terminal branches, but each of these may again divide, almost at their origin, into two or more stems, so that a number of parallel vessels, one of which usually represents the cystic branch, ascend to the liver. Occasionally the cystic branch or an accessory cystic branch arises from the gastro-duodenal, and this latter vessel may arise from the cœliac axis while the liver and gall-bladder are supplied by a stem which arises from the superior mesenteric (Brewer).

(*c*) **The Splenic Artery.**—The splenic artery (**a. lienalis**) (Figs. 720, 721) is the largest branch of the cœliac axis. It passes in a more or less tortuous course over the left crus of the diaphragm and along the upper border of the pancreas, lying behind the posterior wall of the lesser sac of the peritoneum. It crosses the anterior

FIG. 721.



Cœliac axis and its branches: stomach has been removed and transverse colon turned up.

surface of the left suprarenal capsule and the upper part of the left kidney, and, passing between the two layers of the lieno-renal ligament, reaches the hilum of the spleen, where it breaks up into a number of branches which pass to the substance of that organ.

Branches.—(*aa*) **Pancreatic branches** (**rami pancreatici**) are given off from the splenic artery throughout the entire extent of its course along the upper border of the pancreas and supply that organ. One branch, much larger than the others (**a. pancreatica magna**), arises at about the junction of the middle and left thirds of the artery and, entering the substance of the gland obliquely, passes from left to right along with the pancreatic duct.

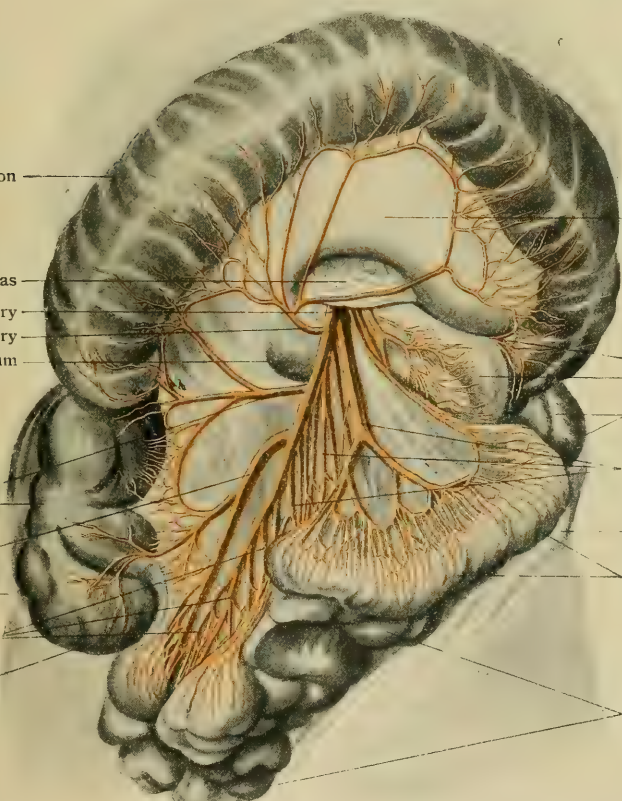
(*bb*) **Short gastric branches** (**aa. gastricae breves**), variable in number, are given off either from the terminal portion of the artery or from some of its terminal branches. They pass between the layers of the gastro-splenic omentum to the left end of the greater curvature of the stomach, and, passing upon the surfaces of that organ, supply it, and anastomose with the cardiac branches of the gastric artery and with the branches of the left gastro-epiploic.

(*cc*) The **left gastro-epiploic artery** (**a. gastroepiploica sinistra**) arises close to the termination of the splenic and passes between the layers of the gastro-splenic omentum to the greater curvature of the stomach, along which it runs between the layers of the greater omentum, and terminates by inosculating with the right gastro-epiploic branch of the hepatic artery. Throughout its course it gives off numerous branches which pass, on the one hand, upward upon both surfaces of the stomach to anastomose with branches of the gastric artery, and, on the other hand, downward into the greater omentum.

Variations.—The splenic is remarkably constant in its course and branches. It may arise directly from the aorta, and it has been observed to give off the gastric artery, a large branch to the left lobe of the liver, and the middle colic artery.

2. **The Superior Mesenteric Artery.**—The superior mesenteric artery (**a. mesenterica superior**) (Figs. 721, 722) arises from the anterior surface of the abdominal aorta, about 1.5 cm. below the cœliac axis. It lies at first behind the pancreas, but, passing downward and forward, it emerges between that organ and the upper border of the third portion of the duodenum and enters the mesentery.

FIG. 722.



Superior mesenteric artery and its branches; transverse colon and stomach have been drawn upward.

It passes downward between the two layers of the mesentery, gradually curving towards the right, and terminates near the junction of the ileum with the cæcum by anastomosing with its own ileo-colic branch.

Branches.—The superior mesenteric artery supplies the whole length of the small intestine, with the exception of the upper part of the duodenum, and also a considerable portion of the large intestine, including the cæcum and appendix, the ascending colon, and about half the

transverse colon. The lower portions of the duodenum and ileum and the large intestine are supplied by branches given off from the concave surface of the artery, while the rest of the small intestine receives its supply from a somewhat variable number of branches which arise from the convex surface.

(*a*) The **inferior pancreatico-duodenal** (**a. pancreaticoduodenalis inferior**) is a small vessel which usually arises from the superior mesenteric just as it emerges from beneath the pancreas, although it occasionally is given off by the uppermost of the intestinal branches. It passes towards the right along the upper border of the third portion of the duodenum, and supplies that portion of the intestine, as well as the neighboring portions of the pancreas, and anastomoses with the superior pancreatico-duodenal branch of the hepatic artery.

(*b*) The **intestinal branches** (**rami intestinales**), also called *vasa intestini tenuis*, are from ten to sixteen in number, and arise from the convex surface of the artery, those branches which arise from the upper portion of the parent stem being, in general, larger than the lower ones. The first two or three branches, as they pass towards the intestine between the two layers of the mesentery, divide into an ascending and a descending branch, and these branches inosculate to form a series of primary arches, which run, in a general way, parallel with the intestine. Lower down, in addition to these primary arches, secondary ones are formed by the inosculation of branches given off proximally to those which form the primary arches; still later, tertiary arches make their appearance, and finally the arrangement becomes so complicated as to resemble a net-work rather than a definite series of arches. From the convex surfaces of the primary arches a large number of parallel straight branches pass to the intestine and are distributed to its walls. They rarely branch in their course through the mesentery, and are usually distributed to one side of the intestine and then to the other alternately. The rich anastomosis which occurs between the various intestinal branches, and which varies greatly in its complexity, serves to equalize the supply of blood to the entire length of the intestine and to permit of abundant and rapidly collateral circulation to any portion of the tract from which the direct supply may be cut off by pressure exerted during peristalsis.

(*c*) The **ileo-colic artery** (**a. ileocolica**) arises about half-way down the concave surface of the superior mesenteric either independently or in common with the right colic branch. It passes downward and outward, beneath the peritoneum, towards the ileo-cæcal junction, giving off branches which inosculate with the right colic above, with the terminal portion of the superior mesenteric below, and, in the interval, with one another to form a series of arches from which branches are supplied to the terminal portion of the ileum, to the cæcum and the vermiform appendix (**a. appendicularis**) and to the lower third of the ascending colon.

(*d*) The **right colic artery** (**a. colica dextra**) arises from the concave surface of the superior mesenteric either a short distance above or in common with the ileo-colic. It runs towards the right, behind the peritoneum, passing over the right psoas muscle, the ureter, and the spermatic (or ovarian) vessels, and as it approaches the ascending colon it divides into an ascending and a descending branch. These inosculate respectively with the middle colic and the ileo-colic to form arches, from which branches pass to the upper two-thirds of the ascending and to a portion of the transverse colon.

(*e*) The **middle colic artery** (**a. colica media**) arises from the concave surface of the superior mesenteric a little below the origin of the inferior pancreatico-duodenal branch. It passes forward and downward between the two layers of the transverse mesocolon, and divides into a right and left branch which inosculate respectively with the right colic and with the left colic branch of the inferior mesenteric to form arches, from which branches pass to the transverse colon.

Variations.—Considerable variation occurs in the number and position of the branches of the superior mesenteric artery and also in the complexity of the anastomoses which occur between these. In addition to those usually present, branches may be sent to any of the neighboring organs, such as the liver, stomach, and spleen, and the artery may give rise to the hepatic, as already pointed out, or to the gastro-duodenal, or even the gastric or renal artery. It has been observed to supply the place of the inferior mesenteric artery when that vessel was lacking, giving off left colic, sigmoid, and superior hemorrhoidal branches.

From the embryological stand-point the superior mesenteric represents the intestinal branch of the omphalo-mesenteric artery, which, during the early months of fœtal life, passes outward through the umbilicus to be distributed upon the surface of the yolk-sac. Usually this artery disappears, except in so far as it is concerned in the formation of the superior mesenteric artery; but it has been observed to persist, appearing as a branch of the superior mesenteric which is continued forward in a strand of connective tissue from the ileum to the umbilicus, where it anastomoses with the epigastric artery and sends a branch upward along with the round ligament of the liver.

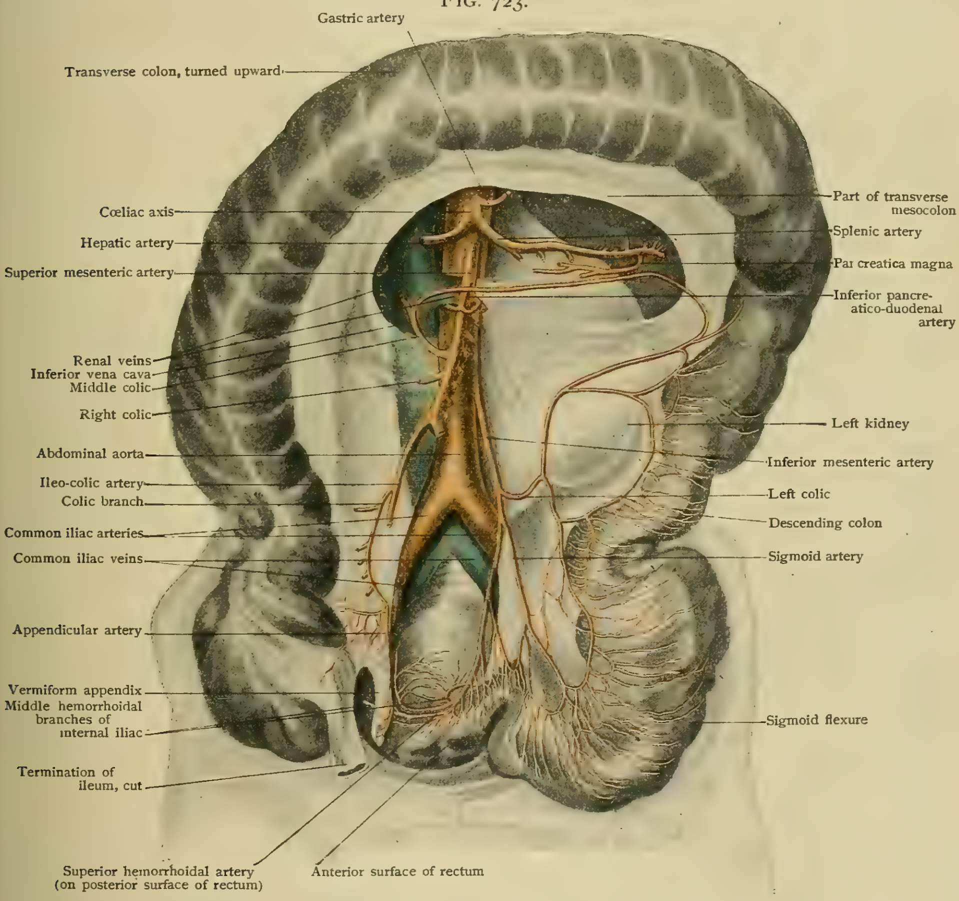
3. **The Inferior Mesenteric Artery.**—The inferior mesenteric artery (**a. mesenterica inferior**) (Fig. 723) arises from the anterior surface of the abdominal aorta from 3–4 cm. above the bifurcation of that vessel into the two common iliacs.

It passes downward and to the left, beneath the peritoneum and resting upon the left psoas muscle, and, after having crossed the left common iliac, it terminates upon the upper portion of the rectum, this terminal portion being called the *superior hemorrhoidal artery*.

Branches.—(*a*) The **left colic artery** (**a. colica sinistra**) arises shortly below the origin of the artery and passes upward and to the left. It divides into an ascending and a descending branch, the former of which passes between the two layers of the transverse mesocolon to inosculate with the middle colic branch of the superior mesenteric, while the descending branch, entering the sigmoid mesocolon, anastomoses with the sigmoid arteries. From the arches thus formed branches pass to the left portion of the transverse colon and to the whole of the descending colon.

(*b*) The **sigmoid branches** (**aa. sigmoideae**), two or three in number, are given off as the inferior mesenteric crosses the left common iliac. They run downward and to the left over the

FIG. 723.



Superior and inferior mesenteric arteries; small intestine has been removed.

left psoas muscle and, passing between the two layers of the sigmoid mesocolon, give off ascending and descending branches which anastomose with one another and with the left colic and superior hemorrhoidal arteries, forming with them arches from which branches pass to the sigmoid colon.

(*c*) The **superior hemorrhoidal artery** (**a. haemorrhoidalis superior**) is the terminal portion of the inferior mesenteric. It descends into the pelvis lying between the folds of the mesentery of the pelvic portion of the colon, and at the junction of the colon and rectum divides into two branches which continue down the sides of the rectum, supplying that viscus and making anastomoses with the middle hemorrhoidal from the internal iliac and with the inferior hemorrhoidal from the internal pudic.

Variations. The inferior mesenteric artery may be wanting, its place being supplied by branches from the superior mesenteric. It occasionally gives rise to the middle colic artery or to an accessory renal vessel.

4. **The Inferior Phrenic Arteries.**—The inferior phrenic arteries (**aa. phrenicae inferiores**) (Fig. 718) most frequently arise from the abdominal aorta, either singly or by a common trunk, immediately beneath the aortic opening of the diaphragm and above the cœliac axis. They are directed upward and laterally over the crura of the diaphragm, to which they supply branches, and in this portion of their course they also give off **superior suprarenal branches** (**rami suprarenales superiores**) to the suprarenal bodies. Over the region where the crura pass into the diaphragm proper, each inferior phrenic divides into an internal and an external branch. The former is the smaller of the two, and passes inward towards the œsophageal opening of the diaphragm, where it anastomoses with its fellow of the opposite side to form an arterial ring from which branches descend upon the œsophagus, supplying the lower portion of that structure and anastomosing with the œsophageal branches of the gastric artery.

The external branches are directed laterally upon the under surface of the diaphragm, supplying it. They pass as far forward as the costal and sternal origins of the diaphragm, anastomosing with the musculo-phrenic, superior epigastric, and superior phrenic branches of the internal mammary arteries, while other branches ramify over the lateral portions of the diaphragm, anastomosing with the lower intercostals and perforating the central tendon to anastomose with the pericardial arteries and with the diaphragmatic branches of the thoracic aorta.

Variations.—The inferior phrenic arteries are very variable in their origin. One frequently takes its origin from the cœliac axis or from one of its branches, or both may arise from the axis. They have also been observed to arise from the superior mesenteric or the renal, or from the abdominal aorta below the superior mesenteric. They also vary considerably in volume.

5. **The Suprarenal Arteries.**—The suprarenal arteries, sometimes termed the *middle suprarenals* (**aa. suprarenales mediae**) (Fig. 718) to distinguish them from the suprarenal branches of the inferior phrenic and renal arteries, are a pair of small but constant branches which arise from the sides of the abdominal aorta, almost opposite the origin of the superior mesenteric artery. They pass outward and slightly upward over the crura of the diaphragm to the suprarenal bodies, where they anastomose with the other suprarenal branches.

6. **The Renal Arteries.**—The renal arteries (**aa. renales**) (Figs. 718, 1591) are two large stems which arise from the sides of the abdominal aorta a little below the origin of the superior mesenteric. Usually the two arteries are opposite each other, but frequently that of the right side arises a little lower down than that of the left side. They are directed outward and slightly downward towards the kidneys, each artery, before reaching the hilum, dividing into from three to five branches, which enter the substance of the kidney independently at the hilum.

Relations.—In their course towards the kidneys the renal arteries rest upon the lower portions of the crura of the diaphragm and more laterally upon the upper part of the psoas muscles. The right artery is somewhat longer than the left, owing to the position of the abdominal aorta a little to the left of the median line, and it passes behind the inferior vena cava. Both vessels are almost concealed beneath the corresponding renal veins, and at the hilum of the kidney the majority of the terminal branches pass in front of the upper portion of the ureter, only one or two passing behind it.

Branches.—Near its termination each artery gives off branches which pass to the adipose tissue surrounding the kidney, and a **ureteral branch** which supplies the upper part of the ureter, anastomosing with the ureteral branch of the spermatic (or ovarian) artery. More proximally it gives origin to an **inferior suprarenal branch** (**a. suprarenalis inferior**) which passes upward to the lower part of the suprarenal body and anastomoses with the other branches which go to that structure.

Variations.—Not infrequently the division of the renal arteries into their terminal branches takes place early, sometimes immediately at their origin, several stems arising directly from the aorta and passing outward to the kidney. Accessory renal branches may arise from the abdomi-

nal aorta or from the middle sacral, the common iliac, the internal iliac, or the inferior mesenteric, and occasionally the renal artery proper may be lacking and its place taken by a vessel from one or other of these origins. These accessory arteries frequently enter the substance of the kidney elsewhere than at the hilum.

The two renal arteries may arise by a common trunk from the anterior surface of the aorta, and they occasionally give off branches which are either accessory to or replace vessels normally arising elsewhere. Thus they have been observed to give rise to the inferior phrenics, the right branch of the hepatic, the spermatics, branches to the pancreas and colon, and one or more of the lumbar arteries.

7a. **The Spermatic Arteries.**—The spermatic arteries (**aa. spermaticae internae**) (Figs. 718, 1591) are two slender vessels which arise from the anterior surface of the aorta a little below the renals. They are directed downward, and slightly outward and forward, towards the lower part of the anterior abdominal wall, and as they approach this each vessel curves inward towards the median line to reach the internal abdominal ring. Here it comes into relation with the vas deferens and becomes enclosed with it in the spermatic cord. Embedded in this structure, it traverses the inguinal canal and passes into the scrotum, terminating just above the testis by dividing into branches which pass to that organ and to the epididymis.

Relations.—In its course through the abdomen the left spermatic artery lies behind the peritoneum and rests upon the psoas muscle. About the middle of this portion of its course it crosses obliquely in front of the ureter, and lower down has resting upon it the sigmoid colon. The right artery at first lies in the root of the mesentery ; it descends obliquely upon the anterior surface of the inferior vena cava and then, crossing the ureter obliquely, comes to lie behind the terminal portion of the ileum and frequently behind the vermiform appendix.

In the pelvic and inguinal portions of their course the relations of both arteries are the same. The vessels rest upon the psoas muscle to the outer side of the external iliac artery, and cross the lower part of that vessel and the accompanying vein to reach the internal abdominal ring. In their course down the spermatic cord the arteries lie behind the anterior group of the spermatic veins and in front of the vas deferens.

Branches.—In addition to the terminal (*a*) **testicular** and (*b*) **epididymal branches**, each spermatic artery gives off—

(*c*) An **ureteral branch** which is distributed to the middle portion of that duct, anastomosing with the ureteral branch of the renal artery above and with branches from the inferior vesical artery below.

(*d*) **Cremasteric branches** are given off in the course through the spermatic cord and supply the cremaster muscle, anastomosing with the cremasteric branch of the deep epigastric artery.

Variations.—The spermatic arteries occasionally arise by a common trunk, or, on the other hand, they may arise at different levels. They have been observed to arise from the renals, especially the left one, from the suprarenals, or from the superior mesenteric artery.

7b. **The Ovarian Arteries.**—The ovarian arteries (**aa. ovaricae**) (Fig. 726) correspond in the female to the spermatic arteries of the male, and have a similar origin and similar relations in the abdominal portion of their course. Arrived at the pelvis, however, they cross the common iliac arteries and veins and, traversing the suspensory ligament of the ovary, pass inward between the folds of the broad ligament of the uterus, terminating beneath the ovary by inosculating with the uterine artery.

Branches.—Like the spermatic arteries, the ovarian give off (*a*) **ureteral branches**. In addition, they give rise to (*b*) **tubal branches**, which pass to the distal portions of the Fallopian tubes ; (*c*) **ligamentous branches**, which accompany and supply the round ligament of the uterus ; and (*d*) **ovarian branches**, which enter the hilum of the ovary and are distributed to its substance.

8. **The Lumbar Arteries.**—The lumbar arteries (**aa. lumbales**) (Fig. 718) are arranged in four pairs, and take origin from the sides of the abdominal aorta, opposite the four upper lumbar vertebræ. They are directed outward upon the bodies of the vertebræ, the lumbar portion of the sympathetic cord descending in front of them, and

those of the right side also pass beneath the inferior vena cava, while the two upper ones of the same side pass beneath the receptaculum chyli. They then pass beneath the psoas muscle and the branches of the lumbar plexus, the two upper ones also passing beneath the crura of the diaphragm; and then, farther out, they pass beneath the quadratus lumborum, except in the case of the last pair, which lies upon the anterior surface of that muscle. At the outer border of the quadratus they pass between the transversalis and the internal oblique muscles of the abdomen, and are continued onward in the abdominal wall, eventually piercing the internal oblique and reaching the rectus muscle.

Branches.—The lumbar arteries are to be regarded as continuations of the series of intercostal vessels, and, like the thoracic members of the series, each gives off a **dorsal branch** (**ramus dorsalis**). This arises when the vessel lies behind the psoas muscle and is directed posteriorly, soon dividing into (*a*) a **spinal branch** (**ramus spinalis**), which enters the spinal canal through the intervertebral foramen and anastomoses with the anterior and posterior spinal arteries; and (*b*) a **muscular branch**, which is distributed to the muscles and skin of the back. In addition, each lumbar artery gives off numerous branches to the muscles with which it comes into relation.

Variations.—One or more of the lumbar arteries may be wanting and two or more of them may arise by a common stem.

9. **The Middle Sacral Artery.**—The middle sacral artery (**a. sacralis media**) (Fig. 718), which is to be regarded as the continuation of the abdominal aorta, is a small vessel arising from the posterior surface of the aorta immediately above its bifurcation into the two common iliacs. It passes downward in the median line over the last two lumbar, the sacral and the coccygeal vertebræ, and terminates opposite the tip of the coccyx by sending branches to the coccygeal body or Luschka's gland (**glomus coccygeum**).

Branches.—It sometimes gives rise to a fifth pair of lumbar arteries (**aa. lumbales imae**), and lower down it sends off small **lateral branches** which send branches inward to the spinal canal through the anterior sacral foramina and anastomose with the lateral sacral branches of the internal iliac artery. These lateral branches appear to represent a continuation of the intercostal and lumbar series of arteries, the branches which enter the anterior sacral foramina corresponding to the dorsal branches of those vessels.

Variations.—The middle sacral occasionally arises from one or other of the common iliac arteries, and it may give origin to an accessory renal artery.

Practical Considerations.—Some of the *branches of the abdominal aorta*, including the splenic, hepatic, renal, superior and inferior mesenteric, and the ovarian, have been the subject of aneurism.

These aneurisms do not usually attain any great bulk, seldom exceeding the size of a hen's egg. They are apt to be round or oval in shape. Occasionally—especially in the aneurisms of the renal artery—they may almost fill the abdominal cavity. Except when connected with the hepatic, the renal, or the cœliac axis, they are movable, changing their position in the various movements of the body. They may possess also the characteristics of pulsation and bruit. When the cœliac artery is affected the disease cannot be distinguished from aneurism of the parent trunk.

In cases of implication of the hepatic artery the pressure-effects of the tumor give rise to pain in the right side and to jaundice from obstruction of the hepatic, cystic, and common bile-ducts (Agnew).

The renal artery has been found to be aneurismal in a small number of instances, the majority being of traumatic origin. The chief symptoms have been: (*a*) *tumor*, varying in size, situated in the region of the kidney, immovable with respiration or with change of posture, and almost always without impulse or bruit, on account probably of the usual disproportion, in renal aneurisms, between the large aneurismal cavity and the size of the vessel involved; (*b*) *hæmaturia* often but not invariably present; (*c*) *pain* elicited by pressure, or felt in the loin or extending to the genitalia, and sometimes accompanied by retraction of the testis.

These abdominal aneurisms are not uncommonly unsuspected until they have reached a late stage, and may even rupture and cause death from hemorrhage without having caused more than trifling inconvenience. In a number of cases the pain —especially apt to be felt in the back—has been the only symptom complained of. If a pulsating tumor, or one with a bruit, can be felt, it would be proper to approach the region by an intraperitoneal or—in the case of the renals—possibly an extraperitoneal incision, and ligate the artery on the cardiac and distal sides of the sac.

THE COMMON ILIAC ARTERIES.

The common iliac arteries (**aa. iliacae communes**) (Figs. 724, 726) are usually regarded as the terminal branches of the abdominal aorta, although in reality the middle sacral artery forms the morphological continuation of that vessel, the common iliacs being lateral segmental branches comparable to a pair of lumbar or intercostal arteries. They arise opposite the body of the fourth lumbar vertebra and pass obliquely outward, downward, and forward to about the level of the sacro-iliac articulation, where they terminate by dividing into the internal and external iliac arteries.

The two common iliacs diverge from each other at an angle of from 60°–65° in the male and somewhat more (68°–75°) in the female. On account of the position of the abdominal aorta being slightly to the left of the median line, the right artery is slightly longer than the left, and is inclined to the median line at a slightly greater angle.

Relations.—The common iliac arteries are covered by peritoneum, which separates them on the right from the terminal portion of the ileum and on the left from the sigmoid colon. *Anteriorly*, each artery is crossed by the ureter, and in the female by the ovarian artery and vein, and by the branches of the sympathetic cord which pass downward to the hypogastric plexus. The left common iliac is, in addition, crossed by the superior hemorrhoidal branch of the inferior mesenteric artery. *Behind*, the vessel of the left side rests upon the bodies of the fourth and fifth lumbar vertebræ, that of the right side being separated from them by the right common iliac vein and by the upper end of the corresponding vein of the left side. Lower both vessels rest upon the psoas muscle. *Laterally*, they are also in relation with the psoas and with the spermatic artery in the male and, in the case of the vessel of the right side, with the upper part of the right common iliac vein. *Medially*, are the common iliac veins and the hypogastric plexus.

Branches.—The common iliac arteries terminate by dividing into the *external and internal iliac* arteries. In addition, they give rise only to small vessels which pass to the subjacent psoas muscles and to the neighboring peritoneum and lymph-nodes and the ureters.

Variations.—A certain amount of variation occurs in the length of the common iliac arteries, depending largely upon the level at which the bifurcation of the abdominal aorta occurs. One or other vessel may give rise to the middle sacral artery or to an accessory renal artery.

Practical Considerations.—The common iliac artery is very rarely the subject of aneurism. Direct *compression* of the artery may be made by either of the plans described as applicable to the abdominal aorta, and should be applied about one inch below and a half inch to the right or left of the umbilicus. While it is easier to get rid of the intestines, as the vessel is placed more laterally, it is not always easy to avoid compression of the aorta itself.

Ligation of the common iliac may be required for aneurism lower down, especially of the upper part of the external iliac, or for wound, or as a preliminary to or part of the procedure in the removal of pelvic growths.

It may be effected by either: (1) The transperitoneal method, or (2) the extraperitoneal method. 1. A median incision from umbilicus to symphysis, opening the peritoneal cavity, the intestines being kept in the upper segment of the abdomen by pads or by placing the patient in the Trendelenburg position, will give easy access to the vessel. On each side it lies directly beneath the peritoneum, but there are anatomical differences to which Makins has called attention. On the right side the vessel is uncovered by any structure of importance, and may be reached by dividing the peritoneum directly over it vertically. On this side the vena cava

and both common iliac veins are in close relation with the artery, the latter two passing beneath it. On the left side, the inferior mesenteric vessels as they enter the sigmoid mesocolon and pass downward to the rectum cover practically the whole of the artery, and to reach the common iliac comfortably and safely the peritoneum would need to be divided close to the left of the median line of the sacrum and be displaced outward. The vein usually lies on the inner side of and somewhat behind the artery. This manœuvre has the disadvantage of exposing the vein freely, but this would probably give far less trouble than would the numerous mesenteric vessels when swollen by reason of the loss of their peritoneal support.

2. By the extraperitoneal method the vessel is approached through various incisions; the best (Crampton) (especially if it is desirable to apply the ligature at the highest possible point) begins at the tip of the last rib and extends downward to the ilium and forward to the anterior superior spinous process. The abdominal muscles and transversalis fascia are divided at the lower extremity of the wound, the peritoneum separated with the finger from the iliac fascia in a direction corresponding to the line of the crista ilii, the abdominal muscles severed on the same line, and the separation of the peritoneum continued until it is pushed off the psoas and the iliac vessels, which lie on the inner aspect of that muscle. The ureter is raised with the peritoneum and remains attached to it.

The artery may be similarly approached through an incision placed just above Poupart's ligament and very like that used for the exposure of the external iliac. The needle is passed from the vein—*i.e.*, from left to right—in ligating the right common iliac, and from right to left if the vessel of the left side is the subject of operation.

The *collateral circulation* is carried on from above the ligature by (*a*) the internal mammary; (*b*) the superior hemorrhoidal; (*c*) the lumbar; (*d*) the middle sacral; and (*e*) the pudic and obturator of the opposite side, anastomosing respectively with (*a*) the deep epigastric; (*b*) the middle hemorrhoidal (internal iliac); (*c*) the deep circumflex iliac; and (*e*) the pudic and obturator of the other side (*i.e.*, the side of the ligature) from below.

THE INTERNAL ILIAC ARTERY.

The internal iliac artery (**a. hypogastrica**) (Fig. 724) arises from the common iliac and passes almost directly downward in front of the sacro-iliac articulation into the pelvis. Opposite the upper border of the great sacro-sciatic foramen it divides into two main stems, the *anterior* and *posterior divisions*, from which branches of distribution are given off.

Relations.—~~Posteriorly~~ Ant. the internal iliac artery is covered by peritoneum and is crossed obliquely by the ureter. More anteriorly the vessel of the right side is in relation with some coils of the ileum, while that of the left side is in relation to the upper part of the rectum. Posteriorly each artery rests upon the upper part of the external iliac vein, which separates it from the inner border of the psoas muscle, and is accompanied throughout its course by the internal iliac vein.

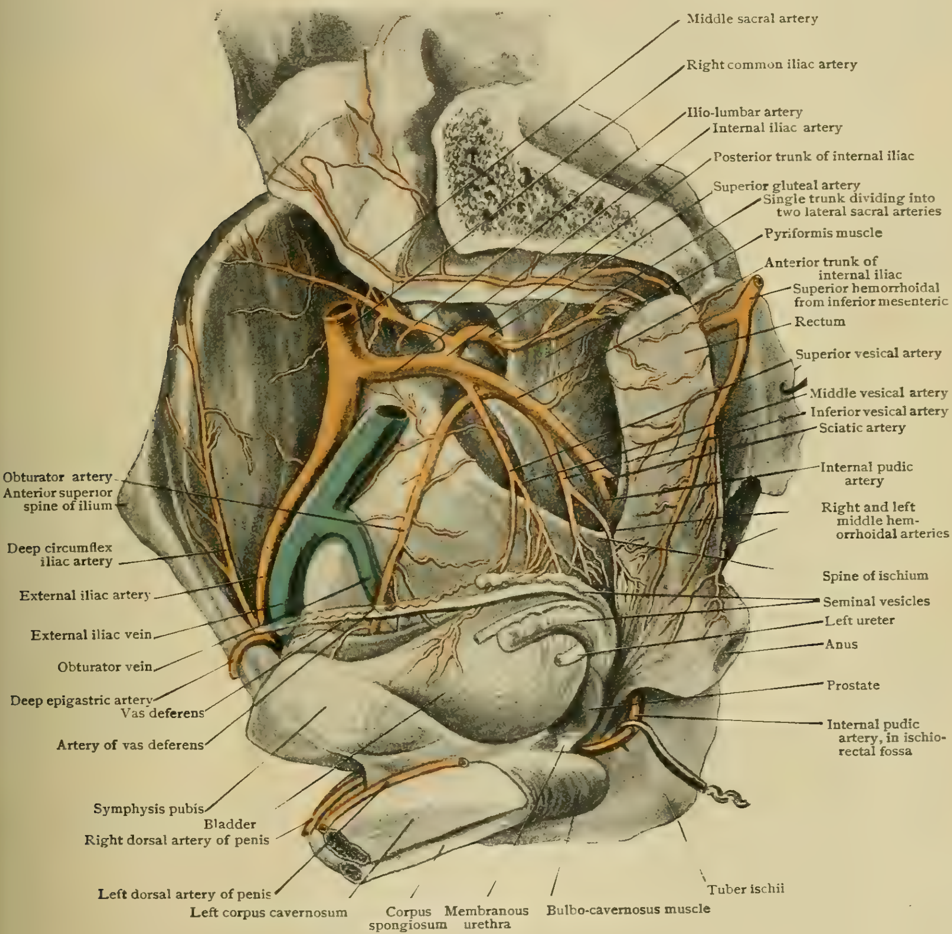
Branches.—From the **main stem** of the artery, before its division, there arises (1) the *ilio-lumbar* artery, and from its **posterior division** (2) the *lateral sacrals*, usually two in number, and (3) the *gluteal*. From the **anterior division** there are given off a *hypogastric axis*, which divides into (4) the *superior vesical*, (5) *inferior vesical*, and (6) *prostatic* or *vaginal* branches, and (7) the *vesiculo-deferential* or *uterine* artery, and, in addition, (8) the *obturator* and (9) *middle hemorrhoidal* arteries, the main stem terminating by dividing into (10) the *internal pudic* and (11) *sciatic* arteries.

Variations.—The internal iliac arteries represent the proximal part of the fœtal umbilical or hypogastric arteries which return the blood from the fœtus to the placenta. During intrauterine life these vessels are large and appear to be the continuation of the common iliacs, passing forward beneath the peritoneum to the lateral walls of the bladder and thence upward upon the anterior abdominal wall to the umbilicus, and thence in the substance of the umbilical cord to the placenta. After birth the arteries diminish in size, and those portions of them which pass across the lateral walls of the urinary bladder and up the abdominal wall become converted into solid fibrous cords which persist throughout life and are known as the **obliterated hypogastric**

arteries. The portions of the arteries which remain patent form the main stems of the internal iliacs, the hypogastric axes and the superior vesical arteries; what are spoken of as the main stems of the anterior divisions of the internal iliacs are really the common trunks by which the sciatic and internal pudic arteries arise from the hypogastric.

In the arrangement of the branches of the fœtal hypogastric arteries four types may be recognized, and corresponding to each of these is an arrangement of the adult internal iliac branches. Leaving out of consideration for the present the smaller branches, the **first type** is that in which two large trunks arise from the hypogastric, the posterior one being the gluteal and the anterior a trunk which divides into the pudic and sciatic. The adult

FIG. 724.



Dissection of pelvis of male, showing right internal iliac artery and its branches.

condition which results from this arrangement is that described above, the main stem of the internal iliac appearing to divide into two divisions, from the anterior of which the hypogastric axis arises.

The **second type** is that in which the three large vessels arise independently from the hypogastric, the resulting adult condition closely resembling that produced from the first type, except that the hypogastric axis seems to arise from the internal pudic, the separation of the anterior division into its two terminal branches occurring high up.

The **third type** is that in which the gluteal and sciatic arteries arise by a common trunk from the hypogastric, the pudic remaining distinct. In the adult, in such cases, the anterior division gives rise to the hypogastric axis and the internal pudic, the sciatic arising from the posterior division.

Finally, in the **fourth type**, which is of rare occurrence, all three large vessels arise from a common stem, in which case there will be no apparent separation of the adult internal iliac into an anterior and a posterior division.

The variations of the smaller branches, which are quite numerous, will be considered in connection with their description. It may be pointed out, however, that, since the superior vesical artery is the persistent portion of the original hypogastric artery and primarily the direct continuation of the hypogastric axis, some of the visceral branches which normally arise from the axis may take their origin from the superior vesical. Furthermore, vessels which embryologically arise from one or other of the great branches of the hypogastric may, on account of the variations in the origin of these, come to arise from the hypogastric axis.

Practical Considerations.—The internal iliac artery is almost never the seat of aneurism. It has been ligated for hemorrhage, for gluteal and sciatic aneurism, and in the treatment of inoperable pelvic growths. It may be approached *intraperitoneally* by the same incision and the same general procedure as employed in ligation of the common iliac (*q.v.*). The vein lies behind and to the inner side, and

FIG. 725.

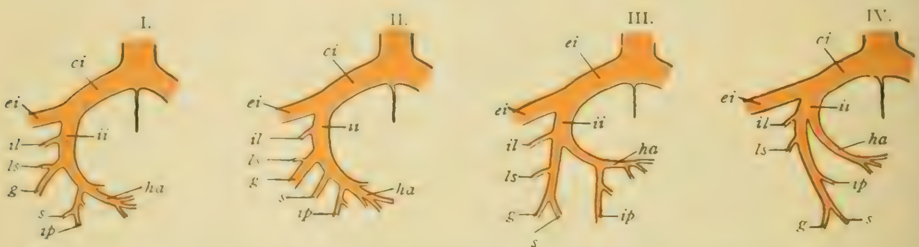


Diagram illustrating four types of arrangement of branches from hypogastric (internal iliac) artery: *ci*, *ei*, *ii*, common, external and internal iliac artery; *il*, ilio-lumbar; *ls*, lateral sacral; *g*, gluteal; *s*, sciatic; *ip*, internal pudic; *ha*, hypogastric axis.

by reason of its size and its close proximity to the vessel must be very carefully dealt with. The needle should be passed from within outward. The relation of the ureter, which crosses the vessel obliquely from without inward and downward, and of the hypogastric plexus should be borne in mind.

In the *extraperitoneal* method the incision and procedure are just as in extraperitoneal ligation of the external iliac (page 819), except that the separation of the peritoneum from the iliac fascia must be carried to a higher level.

The *collateral circulation* is carried on chiefly through (*a*) the inferior mesenteric; (*b*) the circumflex iliac; (*c*) the middle sacral; (*d*) the deep femoral; (*e*) the obturator and internal pudic of the opposite side, all of which carry blood from above the ligature into (*a*) the hemorrhoidal branches of the internal iliac; (*b*) the ilio-lumbar; (*c*) the lateral sacral; (*d*) the sciatic and gluteal; and (*e*) the corresponding vessels of the other side (*i. e.*, the side of the ligature).

1. **The Ilio-Lumbar Artery.**—The ilio-lumbar artery (**a. ilio-lumbalis**) (Fig. 724) is most frequently given off from the main stem of the internal iliac, shortly above its separation into the anterior and posterior divisions. Not infrequently, however, it is a branch of the posterior division. It passes upward and outward towards the brim of the pelvis, crossing in front of the lumbo-sacral nerve and behind the external iliac artery, beyond which it passes beneath the psoas muscle. On reaching the crest of the ilium it divides into two

Branches.—(*a*) The **lumbar branch** (**ramus lumbalis**) is directed upward and backward beneath the psoas and supplies that muscle and the quadratus lumborum. It sends a spinal branch (*ramus spinalis*) through the intervertebral foramen between the last lumbar and first sacral vertebræ, and anastomoses with branches of the last lumbar artery.

(*b*) The **iliac branch** (**ramus iliacus**) passes outward beneath the psoas and ramifies upon the surface of the iliacus muscle, supplying it and usually giving off a nutrient branch to the ilium.

2. **The Lateral Sacral Arteries.**—The lateral sacral arteries (**aa. sacrales laterales**) (Fig. 724) are usually two in number, and arise from the posterior division of the internal iliac. The **superior** one passes downward and inward to the first anterior sacral foramen, and passes through it to supply the spinal membranes and anastomose

with the other spinal arteries. The **inferior** artery passes at first inward and then downward upon the surface of the sacrum, parallel to the middle sacral artery, with which it anastomoses at the tip of the coccyx and also, by delicate transverse branches, opposite each sacral vertebra. Opposite each anterior sacral foramen that it passes —*i.e.*, opposite the second, third, and fourth—it gives off a branch (**ramus spinalis**) which enters the foramen and behaves like the spinal branch of the superior artery. In its downward course the inferior lateral sacral lies to the outer side of the sacral portion of the sympathetic cord and crosses the slips of origin of the pyriformis muscle.

Variations.—Very frequently the two lateral sacral arteries arise by a common stem, and occasionally the branch which enters the second anterior sacral foramen arises independently. In all probability the longitudinal stem of the inferior artery is to be regarded as having been formed by the direct anastomosis of ascending and descending twigs from the lateral branches of the middle sacral, each of which is serially homologous with the lumbar and intercostal arteries. The process is similar to what has occurred in the formation of the vertebral artery (page 721).

3. **The Gluteal Artery.**—The gluteal artery (**a. glutaea superior**) (Fig. 727) is the continuation of the posterior division of the internal iliac. It is the largest of all the branches of that vessel, and passes backward between the lumbo-sacral cord and the first sacral nerve to the upper border of the great sacro-sciatic foramen. It passes through the foramen, in company with the superior gluteal nerve, above the pyriformis muscle, and soon after making its exit from the pelvis divides into a superficial and a deep branch.

Branches.—(a) The **superficial branch** (**ramus superior**) soon divides into a number of branches which enter the upper portion of the gluteus maximus, some supplying that muscle, while others traverse it to supply the skin over the upper part of the gluteal region. One branch, larger than the others, passes outward along the upper border of the origin of the gluteus medius almost to the anterior superior spine of the ilium, anastomosing with branches of the external circumflex iliac artery.

(b) The **deep branch** (**ramus inferior**) soon divides into two branches. (aa) The *superior branch* passes outward along the upper border of the gluteus minimus almost to the anterior inferior spine of the ilium, where, under cover of the tensor vaginæ femoris, it anastomoses with the descending branch of the external circumflex iliac; it sends branches to both the gluteus medius and minimus. (bb) The *inferior branch* passes outward and downward, over the surface of the gluteus medius, towards the greater trochanter of the femur, and gives branches to both the gluteus medius and minimus and to the hip-joint.

4. **The Superior Vesical Artery.**—The superior vesical artery (**a. umbilicalis**) (Fig. 724) represents the original main stem of the fœtal hypogastric artery, and consequently takes its origin from the hypogastric axis and is continuous anteriorly with the fibrous cord which represents the obliterated hypogastric artery (Fig. 728). It passes forward, beneath the peritoneum, towards the urinary bladder, and as it approaches that structure gives off branches to it (**aa. vesicales superiores**) which ramify over its surface and sides and supply its upper and middle portions. They anastomose below with branches of the prostatic and inferior vesical arteries.

Variations.—Not infrequently an accessory branch arising from the superior vesical is distributed to the middle and lower portions of the bladder, forming what has been termed the **middle vesical artery** (Fig. 724).

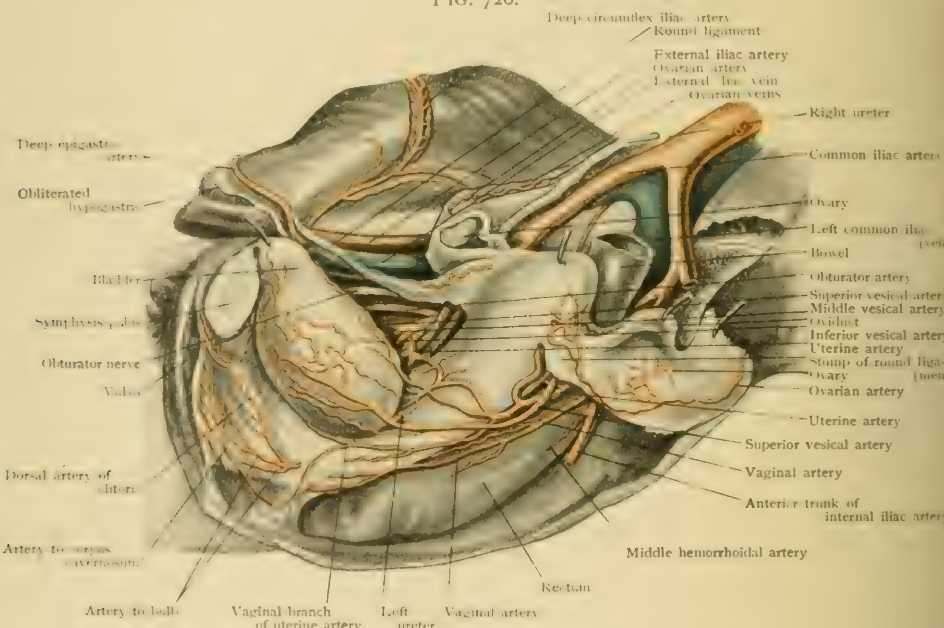
5. **The Inferior Vesical Artery.**—The inferior vesical artery (**a. vesicalis inferior**) (Fig. 724) may arise from the hypogastric axis, from the anterior division of the internal iliac below the axis, from the middle hemorrhoidal, or quite frequently from the prostatic. It descends towards the lower portion of the bladder, supplying the base and neck of that structure, and also sending branches to the prostate gland and the seminal vesicles in the male. It anastomoses with branches of the prostatic and superior vesical arteries.

Variations.—The inferior vesical is usually a rather slender branch, and may be replaced by vesical branches from the prostatic or by branches of the superior vesical.

6*a*. **The Prostatic Artery.**—The prostatic artery arises either from the hypogastric axis, or, more usually, from a trunk common to it and the inferior vesical or the middle hemorrhoidal. It passes downward, forward, and inward to the lateral surface of the prostate gland, and sends branches into the interior of that structure and also to the base of the bladder, anastomosing with branches of the inferior vesical artery.

6*b*. **The Vaginal Artery.**—The vaginal artery (**a. vaginalis**) (Fig. 726), the homologue of the prostatic artery, arises either from the hypogastric axis, more usually from a trunk common to it and the inferior vesical or middle hemorrhoidal, or from the anterior division of the internal iliac, below the hypogastric axis. It passes downward and inward towards the lower part of the sides of the vagina, where it divides into numerous branches which ramify over the anterior and posterior surfaces of that organ, anastomosing with the corresponding branches of the artery of the other side. It also anastomoses above with the cervical branches of the uterine artery and below with the perineal branches of the internal pudic. By these anastomoses there is usually formed along the median line of both the anterior and posterior surfaces of the vagina a more or less regular vessel which is known as the *azygos artery of the vagina*.

FIG. 726.



Arteries of female pelvis, seen from left side.

Variations.—The vaginal artery occasionally arises from a common trunk with the uterine. Frequently, as a result of its precocious division, it is represented by two or more vessels.

7*a*. **The Vesiculo-Deferential Artery.**—The vesiculo-deferential artery (**a. deferentialis**) usually arises from the hypogastric axis, but sometimes from the proximal part of the superior vesical or from the anterior division of the internal iliac, below the hypogastric axis. It passes downward, forward, and inward, and, crossing the ureter, gives a branch to the vas deferens and then breaks up into a number of small branches which are distributed to the vesicula seminalis. The **deferential branch,** on reaching the vas, divides into an ascending and a descending branch. The former passes upward along the vas to the internal abdominal ring and thence through the inguinal canal to the neighborhood of the epididymis, anastomosing with branches of the spermatic artery. The descending branch accompanies the vas to the prostate.

7*b*. **The Uterine Artery.**—The uterine artery (**a. uterina**) (Fig. 726) corresponds to the vesiculo-deferential and has a similar origin. It passes at first downward and inward upon the surface of the levator ani, and then inward in a tortuous course

along the base of the broad ligament towards the neck of the uterus. Just before reaching the uterus, usually about 2 cm. (¾ in.) from it, the artery crosses in front of the ureter and then bends upward between the two layers of the broad ligament along the side of the uterus. Arrived at the junction of the Fallopian tube with the uterus, it bends outward along the lower border of the tube, and then, passing beneath the hilum of the ovary, terminates by inosculating with the ovarian artery.

In its course between the layers of the broad ligament the artery is accompanied by the large uterine veins, which almost conceal it, and both artery and veins are enclosed in a rather dense sheath of areolar tissue. During pregnancy the artery becomes much enlarged, and its course, as well as that of its branches, becomes exceedingly sinuous and even spiral.

Branches.—(*a*) As the uterine artery crosses the renal duct, a **ureteral branch** is supplied to the ureter. On reaching the sides of the uterus, it gives off—

(*b*) One or several **cervical branches.** These pass to the cervix and divide into numerous branches which supply that portion of the uterus and the upper part of the vagina. They are relatively long and tortuous, and anastomose below with the branches of the vaginal arteries. Throughout the rest of its course along the sides of the uterus it gives off numerous—

(*c*) **Uterine branches,** which, although tortuous, yet differ from the cervical branches in being rather short. They pass to both the anterior and posterior surfaces of the uterus and supply its body and fundus, and it is to be remarked that both these branches and the cervical ones diminish rapidly in calibre as they branch upon the surface of the uterus, so that at the middle line of the organ only exceedingly minute twigs are to be found.

From the portion of the artery that runs outward along the lower border of the Fallopian tube—

(*d*) **Tubal branches** (**rami tubarii**) are given off. One of these, much stronger than the others, arises just before the uterine inosculates with the ovarian artery, and passes outward along the tube to its fimbriated extremity, sending branches to it through its entire course.

(*e*) **Ovarian branches** (**rami ovarii**) to the ovary are finally given off from the uterine artery in the vicinity of its anastomosis with the ovarian.

8. **The Middle Hemorrhoidal Artery.**—The middle hemorrhoidal artery (**a. haemorrhoidalis media**) (Fig. 726) is somewhat variable both in its origin and in its size. It arises either from the anterior division of the internal iliac, below the hypogastric artery, or, as frequently happens, from the inferior vesical or occasionally from the internal pudic. It passes along the lateral surface of the middle portion of the rectum, giving off branches which, in addition to aiding in supplying the vagina and communicating with the vaginal arteries, anastomose above with the superior hemorrhoidal from the inferior mesenteric and below with the inferior hemorrhoidal from the internal pudic.

9. **The Obturator Artery.**—The obturator artery (**a. obturatoria**) (Fig. 724) arises from the anterior division of the internal iliac, below the hypogastric axis. It passes forward along the lateral wall of the pelvis, resting upon the pelvic fascia which covers the upper portion of the internal obturator muscle, and having the obturator nerve immediately above it and the vein below. Just before reaching the anterior wall of the pelvis it is crossed by the vas deferens in the male, as it passes downward from the internal abdominal ring, and then it pierces the pelvic fascia and makes its exit from the pelvic cavity through the obturator canal, on emerging from which it divides into two terminal branches, an internal and an external.

Branches.—*Within the pelvis* the obturator artery gives off several small branches, of which the more important are—

(*a*) An **iliac branch,** which is given off near the origin of the obturator and passes up to the iliac fossa, supplying the ilio-psoas muscle, giving nutrient branches to the ilium and anastomosing with the iliac branch of the ilio-lumbar artery.

(*b*) **Muscular branches,** which are distributed to the obturator internus and the levator ani.

(*c*) **Vesical branches,** which pass to the bladder beneath the false lateral ligament and anastomose with branches from the superior vesical; and

(*d*) A **pubic branch** (**ramus pubicus**) which arises just before the artery enters the obturator canal and ascends upon the posterior surface of the os pubis to anastomose above with the pubic branch of the deep epigastric artery.

Outside the pelvis the obturator artery divides into an external and an internal branch.

(*e*) The **external branch** passes around the external border of the obturator foramen, beneath the external obturator muscle, and terminates by anastomosing with the internal branch and with the internal circumflex from the deep femoral. Near its origin it gives off—

(*aa*) An *internal branch*, which passes downward on the posterior surface of the obturator membrane, under cover of the internal obturator muscle, to the tuberosity of the ischium, and it also gives rise to

(*bb*) An *acetabular branch* (ramus acetabuli), which passes through the cotyloid notch and supplies the fatty tissue occupying the bottom of the acetabulum.

(*f*) The **internal branch** runs around the inner border of the obturator foramen, beneath the external obturator muscle, and terminates by anastomosing with the external branch.

Variations.—The obturator artery varies greatly in its origin, and these variations may be divided into two groups, according as the origin is from the internal or the external iliac system of arteries. While the origin of the vessel from the anterior division of the internal iliac is the most frequent, yet, when compared with all the variations taken together, it occurs in somewhat less than 50 per cent. of cases. Of other origins from the system of the internal iliac there may be mentioned those from the main stem of the iliac before its division, from its posterior division, and from the gluteal artery. Furthermore, its origin may occur from either the sciatic or the internal pudic artery, although such cases are rare.

More frequent and of greater importance from the practical stand-point is the origin from the external iliac system, which occurs in about 30 per cent. of cases. In the immense majority of such cases—in almost twenty-nine out of every thirty—the origin is from the deep epigastric artery, being in the remaining cases from the external iliac distal to the deep epigastric or from the upper part of the common femoral artery. Undoubtedly the primary relations of the obturator artery are with the internal iliac system of vessels, and the origin from the external iliac system is to be regarded as due to the secondary enlargement of an anastomosis normally present and the diminution or inhibition of the original stem of the obturator. Possibilities for such a process are furnished by the normal anastomosis between the pubic branches of the obturator and the external circumflex, and all gradations may be found between the normal arrangement and the complete replacement of the original intrapelvic portion of the obturator by the pubic anastomosis.

The origin of the obturator from the deep epigastric artery (Fig. 728) becomes of importance from the fact that, in order to reach its point of exit from the pelvis, the obturator canal, the vessel must come into intimate relations with the crural ring, and may thus add an important complication to the operation for the relief of femoral hernia (page 1775). There are three possible courses for the vessel in relation to the ring: (1) it may pass inward from its origin over the upper border of the ring and then curve downward and inward along the free border of Gimbernat's ligament to reach the obturator canal; (2) it may bend downward abruptly at its origin and pass in an almost direct course to the obturator canal, passing over the inner surface of the external iliac vein, and therefore down the outer border of the crural ring; or (3) it may pass directly across the ring. As regards the relative frequency of each of these courses it is interesting to note that, according to observations made by Jastschinski, the course along the outer border of the ring is much the most frequent, occurring in 60 per cent. of cases, and being more frequent in females than in males. The course across the ring occurs in about 22.5 per cent. of cases, and is again more frequent in females than in males; while the course along the free edge of Gimbernat's ligament occurs in only 17.5 per cent. of cases, and is more common in males than in females. The differences in the two sexes are associated with the differences in the form of the pelvis and of the obturator foramen.

Practical Considerations.—The gluteal and sciatic arteries have not uncommonly been affected by aneurism which has shown itself as a pulsating compressible tumor in the gluteal region, often with a bruit, and usually causing pain over the nates, extending down the posterior aspect of the thigh—from pressure on the sciatic nerve—and causing lameness.

The gluteal aneurism is situated somewhat farther back in the buttock than the sciatic, which is apt to be farther forward and downward, near the gluteo-femoral crease (Agnew).

Either of these vessels or the internal pudic may require ligature on account of stab-wounds. Serious hemorrhage from a wound in the upper part of the gluteus maximus, *i.e.*, a little below a line from the posterior superior iliac spine to the top of the great trochanter, is likely to proceed from the gluteal artery. Lower, nearer to the fold of the buttock, it may come from the sciatic. The gluteal may be tied through an incision made along the line just mentioned, from the posterior superior spine to the trochanter. With the thigh in inward rotation, the junction of the middle with the upper third of that line indicates about the point where the gluteal artery comes out through the sciatic notch. The fibres of the gluteus maximus are separated, the muscle is relaxed by full extension of the thigh, and the upper bony margin

of the sciatic notch is felt for with the finger through the interspace between the pyriformis and the gluteus medius. The artery may be found as it turns over the bony tip of the sacro-sciatic foramen towards the dorsum ilii. The sciatic artery may be reached through the same incision, the finger then being carried below the pyriformis muscle, when the spine of the ischium and the sharp edge of the sacro-sciatic ligament will serve as landmarks.

The point of emergence of both the sciatic and internal pudic arteries is indicated with sufficient accuracy by the junction of the lower and middle thirds of a line drawn from the tuberosity of the ischium to the posterior superior spine of the ilium. The incision employed should follow the direction of the fibres of the greater gluteal muscle.

10. **The Sciatic Artery.**—The sciatic artery (**a. glutaea inferior**) (Fig. 727) is one of the two terminal branches of the anterior division of the internal iliac. It lies at first internal and posterior to the internal pudic artery, and is directed downward and backward towards the lower part of the great sacro-sciatic foramen, passing usually below the fourth sacral nerve. It makes its exit from the pelvis through the great sacro-sciatic foramen, below the pyriformis muscle, and bends downward beneath the gluteus maximus. It crosses the internal pudic artery at about the level of the spine of the ischium, and in the rest ot its course lies to the inner side of the great sciatic nerve. It descends upon the gemelli, the internal obturator, and the quadratus femoris, and, after giving off its principal branches, is continued down the leg as a slender vessel, the comes nervi ischiadici.

Branches.—*Within the pelvis* the sciatic artery gives off some small and inconstant branches to the internal obturator and pyriformis muscles and to the trunks of the sacral pelvis.

Outside the pelvis it gives rise to several larger branches.

(*a*) The **coccygeal branch** passes inward and pierces the great sacro-sciatic ligament and the gluteus maximus near its origin, terminating in the tissues over the lower part of the sacrum and coccyx.

(*b*) **Muscular branches,** variable in number, pass to the neighboring muscles, some of them being continued beneath the quadratus femoris to reach the capsule of the hip-joint. One branch somewhat larger than the rest can frequently be seen entering the deep surface of the gluteus maximus in company with the inferior gluteal nerve; it supplies the muscle and forms anastomoses with the gluteal artery.

(*c*) An **anastomotic branch** passes transversely outward, usually beneath the great sciatic nerve, towards the greater trochanter of the femur. It gives twigs to the gemelli muscles, and in the neighborhood of the trochanter anastomoses with the terminal branch of the internal circumflex, with the transverse branch of the external circumflex, and, below, with the first perforating artery, completing what is termed the *crucial anastomosis.*

(*d*) **Cutaneous branches,** variable in number, wind around the lower border of the gluteus maximus in company with branches of the small sciatic nerve, and supply the integument over the lower part of the gluteal region.

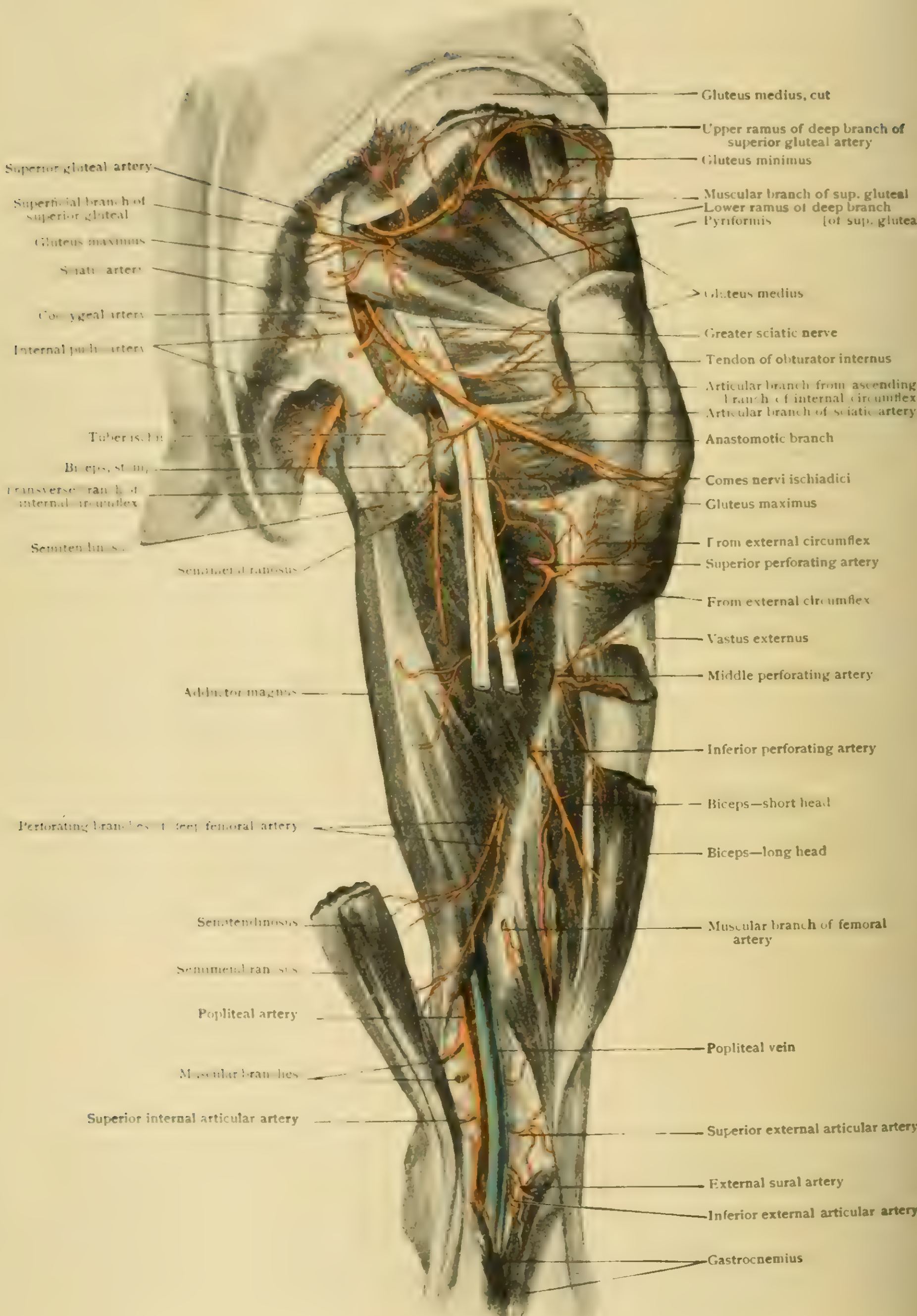
(*e*) The **a. comes nervi ischiadici** is the continuation of the sciatic artery. It is a long, slender branch which passes downward upon or in the substance of the great sciatic nerve, supplying it and anastomosing with the perforating branches of the profunda femoris.

Variations.—The occasional origin of the sciatic from the gluteal artery or from the hypogastric axis has already been described in connection with the variations of the internal iliac (page 808). Occasionally it has a double origin from both the gluteal and the anterior division of the internal iliac, or it may be double, owing to the existence of stems from each of these vessels which pursue independent courses.

In addition to its normal branches, it may give origin to the lateral sacral, the inferior vesical, and the uterine or the middle hemorrhoidal. Especial interest attaches to the comes nervi ischiadici, which occasionally traverses the entire length of the thigh to unite below with the popliteal artery. It represents the original main stem of the sciatic artery, of which the popliteal was primarily the continuation, the connection of that artery with the femoral, and the subsequent diminution of the sciatic being secondary arrangements (page 824).

11. **The Internal Pudic Artery.**—The internal pudic artery (**a. pudenda interna**) (Fig. 727) is the other terminal branch of the anterior division of the internal iliac. It is directed downward in front of the sciatic artery to the lower portion of the great sacro-sciatic foramen, where it makes its exit from the pelvis, passing between

FIG. 727.



Arteries of gluteal region and posterior surface of right thigh.

the pyriformis and coccygeus muscles. It then bends forward, under cover of the gluteus maximus, and, curving beneath the spine of the ischium, passes through the lesser sacro-sciatic notch to enter the ischio-rectal fossa. Its course is then forward along the lateral wall of the fossa, lying with its accompanying vein and the pudic nerve in a fibrous canal known as *Alcock's canal*, formed by a splitting of the obturator fascia near its lower border. At the anterior portion of the ischio-rectal fossa the artery perforates the triangular ligament of the perineum and passes forward between the two layers composing that structure, finally perforating the superficial layer and becoming the dorsal artery of the penis (or clitoris).

Branches.—In the pelvic and gluteal portions of its course the internal pudic, as a rule, gives off only slender **muscular branches** to the neighboring muscles. In its ischio-rectal portion its branches are more important.

(*a*) The **inferior hemorrhoidal arteries** (**aa. haemorrhoidales inferiores**), usually two in number, but frequently only one, which early divides into two or three stems, arise from the internal pudic, just after it has traversed the lesser sacro-sciatic foramen. They perforate the inner wall of Alcock's canal and pass through the fat-tissue which occupies the ischio-rectal fossa towards the lower part of the rectum. They give branches to the ischio-rectal fat-tissue, to the sphincter and levator ani, to the gluteus maximus, to the skin over the ischio-rectal and anal regions, and to the lower part of the rectum, anastomosing above with the middle hemorrhoidal branches of the internal iliac.

(*b*) The **superficial perineal artery** (**a. perinei**) arises just before the internal pudic enters the space between the layers of the triangular ligament of the perineum. It is at first directed almost vertically downward, but quickly bending around the posterior border of the superficial transverse muscle of the perineum, near its origin from the ischial tuberosity, it is directed forward and inward in the interval between the ischio-cavernosus and bulbo-cavernosus muscles. In this portion of its course it is covered only by the superficial perineal fascia and the integument, and passes forward to be distributed to the posterior portion of the scrotum in the male and to the labia majora in the female. In its course it gives off numerous cutaneous branches as well as branches to the neighboring muscles. One of these latter, usually somewhat larger than the rest, passes inward towards the median line, beneath the superficial transverse muscle of the perineum, which it supplies, as also the bulbo-cavernosus and external sphincter ani. This is what has been termed the *transverse artery of the perineum*. It anastomoses at the central point of the perineum with its fellow of the opposite side, with other branches from the superficial perineal artery anteriorly and with branches of the inferior hemorrhoidals posteriorly.

In its perineal portion also the internal pudic gives off important branches.

(*c*) The **artery to the bulb** (**a. bulbi urethrae** or **a. bulbi vestibuli**) arises from the internal pudic a short distance after it has entered the deep perineal interspace. It is a relatively large vessel in the male, and passes almost horizontally inward towards the median line. Before reaching this, however, it perforates the superficial layer of the triangular ligament, enters the substance of the bulbus urethræ about 15 mm. in front of its posterior extremity, and is distributed to that structure and to the posterior third of the corpus spongiosum and urethra. In the female it is of a lesser calibre than in the male, and is distributed to the bulbus vestibuli.

(*d*) The **urethral artery** (**a. urethralis**) arises usually some distance anteriorly to the artery of the bulb, and, like it, is directed medially, and penetrates the superficial layer of the triangular ligament to enter the substance of the corpus spongiosum. It reaches the corpus spongiosum just behind the symphysis pubis, where the two corpora cavernosa come together to form the penis, and is continued forward in the spongiosum to the glans. It is a somewhat inconstant branch, and is quite small in the female.

(*e*) The **artery of the corpus cavernosum** (**a. profunda penis s. clitoridis**) arises from the internal pudic, just posterior to the lower border of the symphysis pubis, and is directed outward towards the bone. It penetrates the superficial layer of the triangular ligament close to its attachment to the pubic ramus, and enters the corpus cavernosum at about the junction of its middle and posterior thirds. It passes to the centre of the corpus and there divides into a posterior branch which supplies blood to the posterior third of that structure, and an anterior one which distributes to its anterior two-thirds. It is much smaller in the female than in the male.

(*f*) The **dorsal artery of the penis** or **clitoris** (**a. dorsalis penis s. clitoridis**) is the continuation of the main stem of the internal pudic beyond the origin of the artery to the corpus cavernosum. It penetrates the superficial layer of the triangular ligament near its apex, and passes upward in the suspensory ligament of the penis or clitoris to the dorsal surface of that organ, along which it passes, lying to the side of the median line and separated from its fellow of the opposite side by the single median dorsal vein. Laterally to it is situated the dorsal nerve of

the penis (or clitoris), and still more laterally the deep external pudic branch of the common femoral artery. On reaching the glans, it forms an anastomotic circle around the base of that structure, uniting with its fellow of the opposite side. Throughout its course it gives branches to the corpus cavernosum and the integument of the penis or the prepuce of the clitoris

Variations.—The occasional origin from the internal pudic of the inferior vesical, middle hemorrhoidal, and uterine arteries has already been noted. The internal pudic, instead of passing out of the pelvis by the great sacro-sciatic foramen, may be directed forward upon the floor of the pelvis and pass out beneath the pubic symphysis to become the dorsal artery of the penis. More frequently this course is taken by an *accessory internal pudic* which arises from the pudic in cases where this vessel appears to arise from the hypogastric axis, a condition which results in the early division of the common stem from which the sciatic and internal pudic arteries normally arise.

The artery of the bulb may arise opposite the ischial tuberosity and pass obliquely forward and medially across the ischio-rectal fossa, and in some cases it passes at first directly across towards the anus and then bends forward to reach the bulb.

The dorsal artery of the penis or clitoris occasionally unites with its fellow of the opposite side to form a single median artery, or the two arteries of opposite sides may be united by transverse anastomoses. Sometimes a third vessel arises either directly from the anterior division of the internal iliac or from the obturator, even when this vessel takes its origin from the deep epigastric.

Anastomoses of the Internal Iliac.—The internal iliac makes anastomoses with branches of the abdominal aorta and of the external iliac, and with its fellow of the opposite side, and it is through these connections that the collateral circulation may be established.

Of branches communicating with the abdominal aortic system there are the hemorrhoidal branches which anastomose with the superior hemorrhoidal from the inferior mesenteric, the uterine which anastomoses with the ovarian, and the lateral sacrals which anastomose with the middle sacral. Communications with the system of the external iliac are through the sciatic with branches of the profunda femoris, through the ilio-lumbar and gluteal with the external and internal circumflex iliacs, and through the obturator with the deep epigastric through the pubic branches. The anastomoses across the middle line occur between the vesical, prostatic (vaginal), obturator, and internal pudic branches.

THE EXTERNAL ILIAC ARTERY.

The external iliac artery (**a. iliaca externa**) (Figs. 724, 728) extends from the bifurcation of the common iliac, opposite the sacro-iliac articulation, to a point beneath Poupart's ligament midway between the anterior superior spine of the ilium and the symphysis pubis. It there becomes the femoral artery. In the adult the external iliac is usually larger than the internal and is directed more nearly in the line of the common iliac, downward, forward, and outward along the brim of the true pelvis.

Relations.—*Anteriorly*, the artery is covered by peritoneum and is enclosed, together with the vein, in a moderately dense sheath derived from the subperitoneal tissue and termed *Abernethy's fascia*. By the peritoneum it is separated on the right side from the terminal portion of the ileum and sometimes from the vermiform appendix, and on the left from the sigmoid colon. Near its origin it is crossed by the ovarian vessels in the female and sometimes by the ureter; near its lower end it is crossed obliquely by the genital branch of the genito-crural nerve and by the deep epigastric vein. Some lymph-nodes are also found resting upon its anterior surface. *Posteriorly*, it rests upon the iliac fascia, which separates it from the psoas muscle; *medially*, it is crossed near its lower end by the vas deferens in the male and the round ligament of the uterus in the female, and is accompanied throughout its course by the external iliac vein, which lies, however, on a slightly posterior plane. *Laterally*, it is in relation to the genito-crural nerve.

Branches.—In addition to some small twigs to the psoas muscle and to the neighboring lymphatic glands, the external iliac gives origin to (1) the *deep epigastric* and (2) the *deep circumflex iliac* arteries.

Variations.—The external iliac varies considerably in length, according to the level at which the abdominal aorta and the common iliac bifurcate. Independently of this, however, and especially in aged individuals, it is frequently longer than is necessary to reach in a direct

line from the common iliac to beneath Poupart's ligament, and in such cases it makes a more or less pronounced bend which may dip below the brim of the pelvis. In the embryo it is a comparatively small vessel, the main supply of the lower limb being through the sciatic, which is continuous below with the popliteal (page 823). Occasionally this condition is retained, the artery then terminating by becoming the deep instead of the common femoral.

In addition to the usual branches it may give off the obturator (page 814), or an accessory deep epigastric or deep circumflex iliac. Or branches usually arising from the common femoral, such as the superficial external pudic or even the profunda femoris, may arise from it.

Practical Considerations.—The external iliac artery is occasionally the seat of aneurism, and such tumors have been mistaken for malignant growths or for abscess. A swelling with expansile pulsation and bruit can usually be found in the line of the vessel near the brim of the pelvis, and the patient will be unable to extend freely the thigh or the trunk, and will lean forward in walking or standing to relieve the ilio-psoas from pressure. There is apt to be pain in the groin and down the front of the thigh from pressure on the anterior crural nerve, or on the crural branch of the genito-crural.

It may be imperfectly *compressed* just above its termination at the middle of Poupart's ligament, but, as is the case with the common and internal iliacs, the circulation through it is better controlled by pressure on the abdominal aorta. The line of the vessel extends from a point half-way between the pubic symphysis and the anterior superior spinous process to a point a little below and to the left of the umbilicus. The course of the external iliac corresponds to the lower third of this line, the upper two-thirds representing the line of the common iliac.

Ligation of the vessel has been done for aneurism of the common femoral, for hemorrhage, and as a palliative in malignant growths or in elephantiasis of the extremity.

Like the other iliacs, it may be approached by either: (1) the intraperitoneal; or (2) the extraperitoneal route.

1. The incision should be made in the semilunar line, and will thus cross the line of the vessel obliquely. Its lower end should reach Poupart's ligament. Its length will vary (with the thickness of the abdominal wall) from three inches to four inches. The superficial circumflex ilii and the deep epigastric arteries may require ligation. The intestines are displaced upward. At the left side the sigmoid flexure, and on the right the termination of the ileum, may be found in close relation to the vessel. On both sides the spermatic vessels cross it, and their distention (analogous to that of the mesenteric vessels spoken of in connection with ligation of the left common iliac) (page 808), when deprived of their peritoneal support, has been noted (Makins).

The peritoneum over the vessel—on the left side possibly a part of the sigmoid mesocolon—is divided parallel with the long axis of the artery, and the needle is passed from the vein.

2. Ligation by the extraperitoneal method—still preferred by many surgeons in the case of this vessel—is done through an incision parallel with Poupart's ligament, but slightly convex downward, beginning one inch above the anterior superior spinous process of the ilium and ending at the outer pillar of the external abdominal ring. After dividing the abdominal muscles and the transversalis fascia, the separation of the peritoneum from the iliac fascia is begun near the outer extremity of the wound, where the subperitoneal areolar tissue is more abundant and the connection of the peritoneum and the fascia less intimate. After the detachment has been effected (chiefly by means of a finger), the vessel is exposed with the vein lying behind it above and to the inner side near Poupart's ligament, and the anterior crural nerve some distance to the outer side. The needle should be passed from within outward.

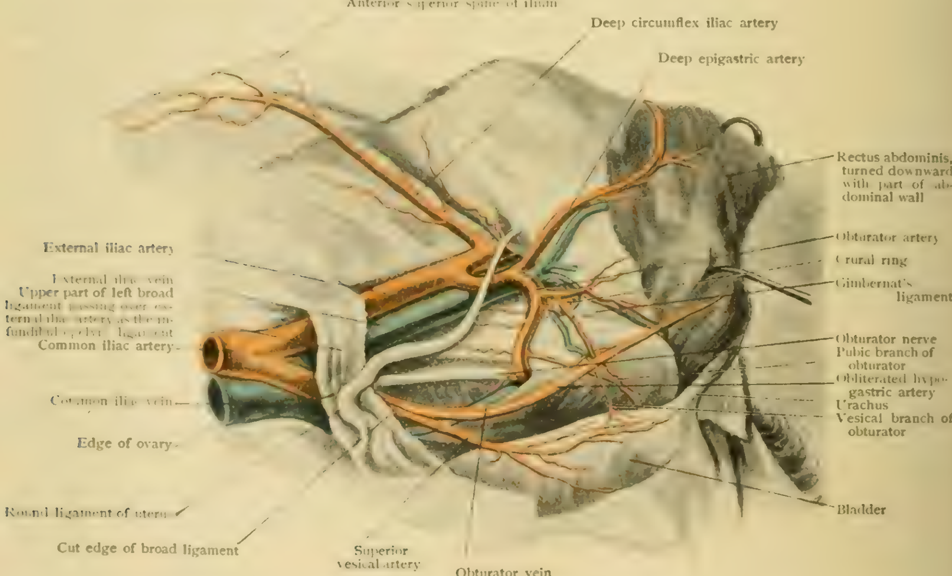
The *collateral circulation* is carried on from above the ligature by (*a*) the lumbar; (*b*) the obturator; (*c*) the sciatic; (*d*) the gluteal; (*e*) the internal pudic; and (*f*) the internal mammary and lower intercostals anastomosing respectively with (*a*) the deep circumflex iliac; (*b*) the internal circumflex; (*c*) the perforating (profunda); (*d*) the external circumflex; (*e*) the external pudic (femoral); and (*f*) the deep epigastric from below.

1. **The Deep Epigastric Artery.**—The deep epigastric artery (**a. epigastrica inferior**) (Fig. 728) arises from the anterior surface of the external iliac, a short distance above where it passes beneath Poupart's ligament. Immediately after its origin it bends downward and medially to pass the lower border of the internal abdominal ring, being crossed in this situation by the vas deferens in the male and the round ligament of the uterus in the female. It then curves upward and medially along the medial border of the internal abdominal ring and ascends along the outer border of Hesselbach's triangle (page 526), of which it forms the lateral boundary. Throughout this portion of its course it lies between the peritoneum and the transversalis fascia, but at about the level of the fold of Douglas, in the posterior surface of the sheath of the rectus abdominis, it pierces the fascia and ascends between the muscle and the posterior layer of its sheath, eventually entering the substance of the muscle, where it terminates by anastomosing with the superior epigastric branch of the internal mammary artery.

Branches.—Throughout its course the deep epigastric artery gives off a number of branches.

(*a*) The **cremasteric branch** (**a. spermatica externa** in the male, **a. ligamenti teretis** in the female) is given off a short distance beyond the origin of the deep epigastric and accompanies

Fig. 728.



Portion of left half pelvis of female subject viewed from above and right side, showing obturator artery arising from deep epigastric.

the spermatic cord or round ligament of the uterus through the inguinal canal. In the male it supplies the cremaster muscle and the spermatic cord, anastomosing with the spermatic and deferential arteries, and in the female, in which it is small, it supplies the lower part of the round ligament and terminates in the labia majora by anastomosing with branches of the superficial perineal artery.

(*b*) The **pubic branch** (**ramus pubicus**) arises a short distance beyond the cremasteric and, passing either above or below the femoral ring, passes downward and inward upon the posterior surface of the os pubis, where it may anastomose with the pubic branch of the obturator. It is by the anastomosis and enlargement of this artery and the pubic branch of the obturator that the latter vessel comes to arise so frequently from the deep epigastric (page 814). And even when the obturator has its normal origin, the anastomosis may render the pubic branch of the deep epigastric of considerable importance in the operation for the relief of femoral hernia.

(*c*) **Muscular branches**, variable in number, are given off, for the most part, from the outer side of the artery and supply the muscles of the abdominal walls. They anastomose with branches of the lower intercostal and lumbar arteries.

(*d*) **Cutaneous branches**, also variable in number, pierce the rectus and the anterior wall of its sheath and supply the skin of the abdomen near the median line.

Variations.—The deep epigastric may arise from the external iliac higher up than usual,—as high, indeed, as a point 6 cm. (2⅜ in.) above Poupart's ligament. In such cases it passes downward and forward upon the anterior surface of the external iliac to reach the abdominal wall. It may also arise below its usual position,—that is to say, from the common femoral artery,—and it may be given off from a trunk common to it and the deep circumflex iliac.

In addition to being frequently the origin of the obturator (page 814), it may be given off from that artery as a result of the enlargement of the anastomosis of the pubic branches of the two arteries and the subsequent degeneration of the proximal portion of the deep epigastric. Occasionally it gives origin to the dorsal artery of the penis or clitoris, an arrangement which also results from its relation to the obturator, from which this artery sometimes arises.

2. **The Deep Circumflex Iliac Artery.**—The deep circumflex iliac artery (**a. circumflexa ilium profunda**) (Fig. 728) arises from the outer surface of the external iliac, a little below the deep epigastric. It passes outward along the lower border of Poupart's ligament, enclosed in a sheath formed by the iliac fascia, and opposite the anterior superior spine of the ilium, or it may be a little beyond it, divides into an ascending and a horizontal branch.

Branches.—In its course it gives branches to the muscles of the abdominal wall and, at the anterior superior spine of the ilium, to the upper part of the sartorius and to the tensor vaginæ femoris.

(*a*) The **ascending branch** pierces the transversalis muscle and ascends directly upward between that muscle and the internal oblique. It sends branches to both these muscles, as well as to the external oblique and the integument, and terminates by anastomosing with the lumbar arteries and with the tenth aortic intercostal (subcostal).

(*b*) The **horizontal branch** continues the course of the main stem. It lies at first a little below the crest of the ilium, but later ascends and perforates the transversalis muscle, passing onward upon the crest of the ilium between that muscle and the internal oblique. It gives off branches which supply the abdominal muscles and anastomose with the lumbar arteries, and terminates by anastomosing with the lumbar branches of the ilio-lumbar.

Variations.—The deep circumflex iliac artery may arise from a common stem with the deep epigastric or from the upper part of the common femoral artery. Not infrequently it gives rise to a branch, shortly after its origin, which passes upward upon the anterior abdominal wall, underneath the transversalis fascia, parallel and lateral to the deep epigastric. This *lateral epigastric artery*, as it has been termed, is occasionally of considerable size, in which case the ascending branch of the circumflex iliac may be more or less reduced. It may ascend to the level of the umbilicus or even above that point, sending branches to the muscles of the abdominal wall.

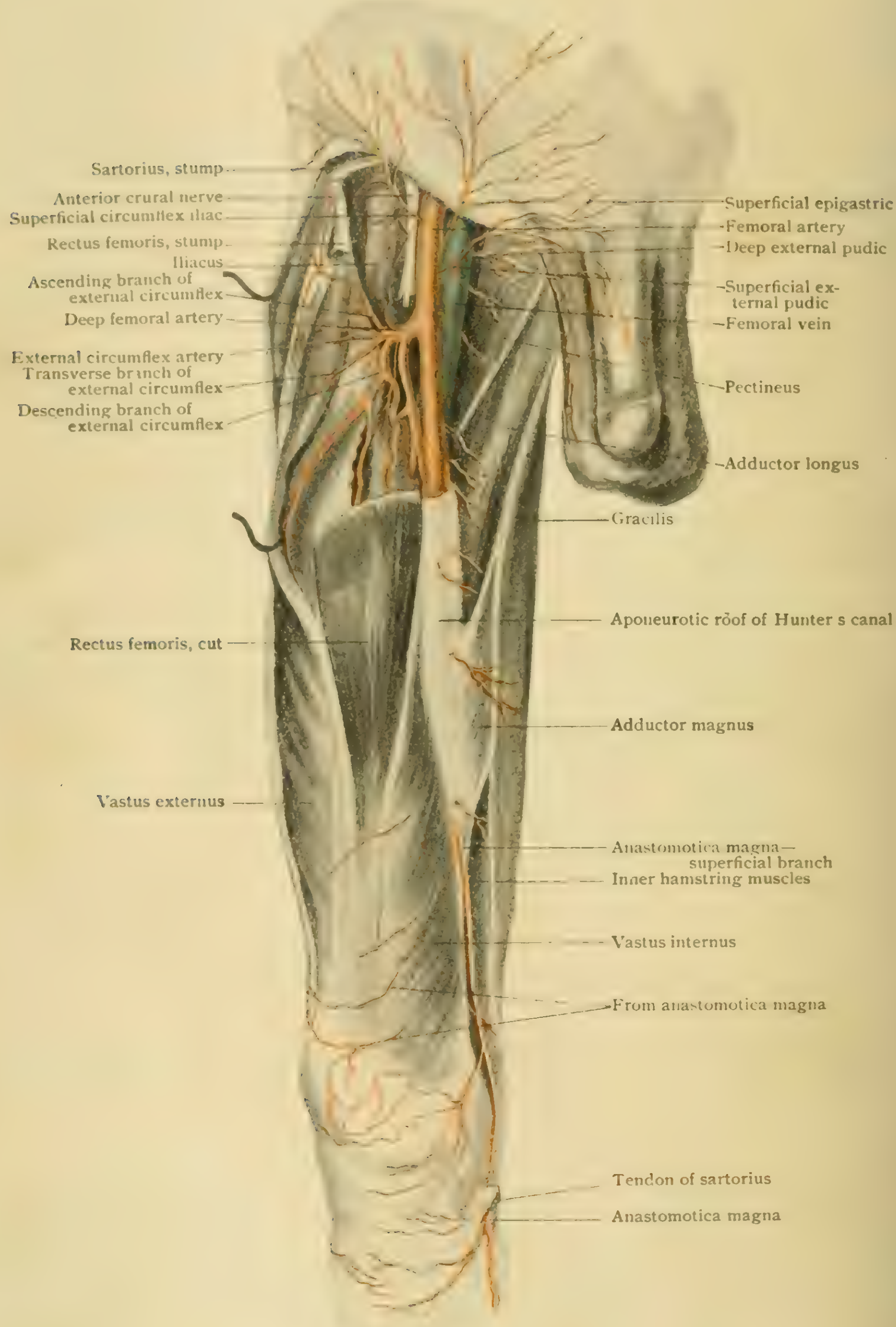
Anastomoses of the External Iliac.—Opportunities for the development of a collateral circulation after ligation of the external iliac artery are afforded by the anastomoses of its deep epigastric branch with the superior epigastric branch of the internal mammary, with the lower aortic intercostals, and with the lumbar arteries. The deep circumflex iliac also makes connections with the lumbar arteries by its ascending and lateral epigastric branches, and, furthermore, anastomoses with the ilio-lumbar and gluteal branches of the internal iliac. Another connection with the internal iliac system is made by the anastomoses of the pubic branches of the deep epigastric and obturator arteries.

Anastomoses between branches of the internal iliac and the femoral arteries are also of importance in this connection, but will be described in connection with the femoral artery (page 831).

THE FEMORAL ARTERY.

The femoral artery (**a. femoralis**) (Figs. 729, 732) is the continuation of the external iliac below Poupart's ligament. Its course is almost vertically downward, with a slight inclination inward and backward, and may be indicated by a line drawn from a point in Poupart's ligament midway between the symphysis pubis and the anterior superior spine of the ilium to the adductor tubercle upon the inner condyle of the femur, when the thigh is flexed upon the pelvis and rotated outward. It terminates at about the junction of the middle and lower thirds of the thigh, where it passes through the adductor magnus muscle, close to the inner surface of the femur, to become the popliteal artery.

FIG. 729.



Arteries of front of thigh; superficial dissection.

Relations.—In its uppermost part, for a distance of about 3 cm. (1½ in.), the femoral artery, together with the accompanying vein, is enclosed within a sheath formed by a prolongation of the transversalis and iliac fasciæ below Poupart's ligament. This *femoral sheath* is funnel-shaped and is divided by partitions into three compartments, the most lateral of which contains the artery, the middle one the femoral vein, while the medial one forms what is termed the *femoral* or *crural canal* (page 625). Below, the walls of the sheath gradually pass over into the connective tissue which invests the vessels.

In the upper half of its course the femoral artery lies in Scarpa's triangle (page 639), while in its lower half it is contained within a space known as *Hunter's canal*, situated between the adductor magnus and vastus medialis muscles and covered in by the sartorius.

In **Scarpa's triangle** the relations of the artery are as follows. *Anteriorly*, it is covered by the integument, the superficial fascia, and the fascia lata, the inner margin of the attenuated portion of the latter fascia, which is known as the cribriform fascia, overlapping it at about the junction of its upper and middle thirds. Superficial to the fascia lata are some of the superficial inguinal lymphatic nodes and the superficial circumflex iliac vein, while deeper and resting upon the upper part of the artery is the crural branch of the genito-crural nerve, and towards the apex of the triangle the internal cutaneous nerve. *Posteriorly*, the artery rests upon the tendon of the ilio-psoas muscle, which separates it from the capsule of the hip-joint, and lower down it lies upon the pectineus muscle. Throughout the lower part of the triangle it is separated from the adductor longus muscle by the femoral vein and by the deep femoral artery and vein. *Medially*, it is in relation above with the femoral vein and below with the adductor longus; *laterally*, with the ilio-psoas muscle and the leash of nerves formed from the anterior crural nerve.

In **Hunter's canal** the artery lies beneath the sartorius muscle and is crossed obliquely from without inward by the long saphenous nerve. *Posteriorly* it rests upon the adductor longus and the adductor magnus, and also upon the femoral vein which, below, comes to lie somewhat laterally as well as posterior to it and is firmly united to the artery by dense connective tissue. To the *inner side* of the artery is the adductor longus above and the adductor magnus below, while to its *outer side*, and partly overlapping it, is the vastus internus.

Branches.—In **Scarpa's triangle** the femoral artery gives off (1) the *superficial epigastric*, (2) the *superficial circumflex iliac*, (3) the *superficial external pudic*, (4) the *deep external pudic*, (5) the *profunda femoris*, and (6) *muscular* branches. In **Hunter's canal** it gives off additional muscular branches and, just before perforating the adductor muscle, (7) the *anastomotica magna*.

The profunda femoris so much surpasses in size the other branches of the femoral that the latter artery is frequently regarded as bifurcating at the point where this vessel arises. The portion of the artery above the bifurcation is then termed the *common femoral*, while its continuation through Scarpa's triangle and Hunter's canal is known as the *superficial femoral*.

Variations.—A comparative study of the arteries of the thigh reveals the fact that the existence of a well-developed femoral artery forming the main blood-channel for the leg is a condition characteristic of the mammalia. In the lower vertebrate groups the sciatic is the principal artery of the thigh, extending throughout the whole length of its flexor surface and becoming continuous below with the popliteal artery, the femoral artery being comparatively insignificant and terminating as the profunda femoris. The peculiar course of the mammalian femoral, starting, as it does, as an artery of the extensor surface of the limb and later perforating the adductor magnus to become continuous with the popliteal upon the flexor surface, is to be regarded, therefore, as a secondary arrangement, and its history is somewhat as follows.

While the sciatic is still the principal vessel of the thigh and retains its connection with the popliteal below, a branch is given off from the femoral which accompanies the long saphenous nerve through Hunter's canal and down the inner surface of the crus, having in this lower portion of its course a superficial position corresponding with that of the nerve. Near the lower part of Hunter's canal this vessel, which is known as the *saphenous artery*, gives off a branch which perforates the adductor magnus and unites with the sciatic, producing an arrangement which, in various degrees of development, may be regarded as characteristic of the mammalia as a group. In man, however, the process goes a step further in that, correlatively with an enlargement of the anastomosis between the saphenous and the sciatic, there is a diminution of the main stem of the latter vessel, so that eventually it becomes reduced to the slender *a. comes*

nervi ischiadici which loses, as a rule, its continuity with the popliteal. That artery now appears to be the continuation of the saphenous (femoral), since there occurs a degeneration of the saphenous below the point where the anastomosing branch is given off. These changes are shown diagrammatically in Fig. 718, (page 849) from which it will be seen that the femoral artery below the origin of the profunda is the upper part of the original a. saphena, the continuation of that vessel down the crus being represented only by the superficial branch of the *anastomotica magna*.

The principal variations which are shown by the femoral artery are associated with these changes which it has passed through in its development, and represent a cessation of the development at one stage or other of its progress. Thus, as already pointed out (page 815), the *comes nervi ischiadici* may remain the principal vessel of the thigh, the femoral terminating in the profunda femoris. Or the development may proceed to the formation of the a. saphena, which may arise either immediately above the profunda femoris, in such case the superficial femoral being wanting and the comes nervi ischiadici still well developed, or else from the lower part of the femoral, just before it pierces the adductor muscle. From this point the vessel, when fully developed, is continued onward with the long saphenous nerve between the adductor magnus and the vastus medialis, and below the knee-joint perforates the crural fascia and is continued superficially down the inner side of the crus, accompanying the long saphenous nerve and vein to the internal malleolus, where it makes connections with the posterior tibial artery and may sometimes persist as a branch of that vessel.

In addition to these anomalies, the femoral artery frequently gives off branches which normally arise from other vessels. Thus it may give rise to the deep epigastric or the deep circumflex iliac, normally branches of the external iliac, or to the external or internal circumflex, normally branches of the profunda femoris. It has also been observed to give origin to the ilio-lumbar artery.

Practical Considerations.—The femoral artery is more often wounded than the brachial on account of the position of its upper half—in Scarpa's triangle—on the anterior surface of the limb, and of its relatively more intimate relation to the bone at its lower end. In the latter region it has been opened by spicules of necrotic bone. Next to the popliteal, it is more frequently the subject of aneurism than any other external arterial trunk. On account of the close relation of the lymphatic glands in and near the groin, the vessel has been opened by ulceration and sloughing in bubo or in carcinoma, and has been involved in sarcomatous growths. The same relation has caused the aneurism to be mistaken for a glandular abscess, an error which has occurred oftener in connection with this vessel than with any other.

Compression of the femoral artery has yielded very satisfactory results in the treatment of popliteal aneurism. The pressure is best applied in a direction backward and outward just below the inferior edge of Poupart's ligament where the vessel can be flattened against the brim of the pelvis—the upper margin of the acetabulum—just outside the ilio-pectineal eminence, only a very thin portion of the ilio-psoas muscle intervening. A little lower, a more fleshy portion of that muscle separates it from the head of the femur, and yet lower the artery has back of it the still less resistant mass of the pectineus and adductor brevis muscles, and more force will be required to obliterate its lumen. At the apex of Scarpa's triangle the pressure must be directed backward and somewhat more outward, and a little lower still more directly outward, the artery at these places being compressed against the femur, the vastus internus intervening.

Extreme flexion of the thigh upon the trunk will occlude the femoral, and has been used successfully in the cure of popliteal aneurism and for the temporary arrest of hemorrhage.

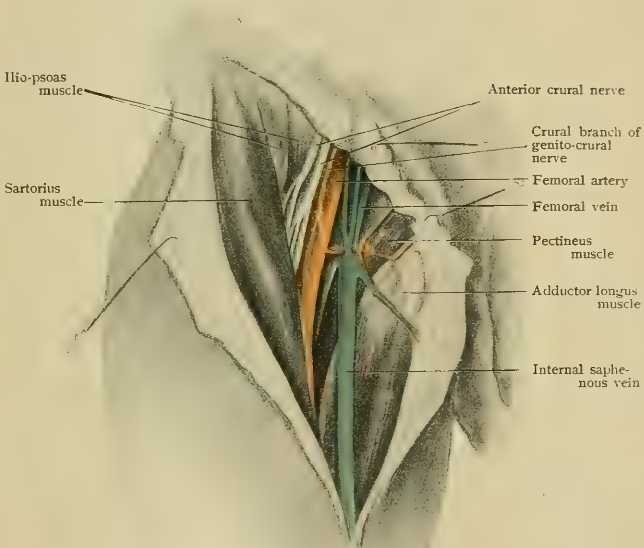
Ligation of the vessel may be done: 1. Between Poupart's ligament and the origin of the profunda—the common femoral (*vide supra*). 2. At the apex of Scarpa's triangle. 3. In Hunter's canal.

1. The common femoral is rarely ligated except as a preliminary to some forms of hip-joint amputations, or for the relief of hemorrhage. In aneurism of the upper portion of the superficial femoral the external iliac is ordinarily preferred because of (*a*) the possibility of a high origin of the profunda. The common femoral is normally only about one and a half inches in length. If its bifurcation occurs above the usual level—the most common variation—the ligature would be in dangerously close proximity to so large a trunk. (*b*) The presence of a number of smaller branches—the deep epigastric and deep circumflex iliac coming off immediately above Poupart's ligament, the superficial epigastric, circumflex iliac, and external pudic, the deep external pudic, and occasionally one of the circumflex arteries (especially the internal),

arising from the femoral. This circumstance likewise interferes with the firmness and security of the clot formation after ligature. (*c*) The fact that ligature of the common femoral cuts off the chief blood-supply to the lower limb also militates against its selection and leads to the choice of the superficial femoral whenever possible, so as to permit the profunda and its branches to maintain a sufficient vascular current. The incision should be begun on the abdomen a little above Poupart's ligament, midway between the anterior superior spine and the symphysis pubis, and extend downward to about two inches below the ligament in the line of the vessel—*vide supra*. The structures to be avoided in approaching the artery are the glands and veins that lie in the fat over the cribriform fascia, the superficial epigastric artery and, when the sheath is exposed, the crural branch of the genito-crural nerve lying upon it near its outer side. The vein is in close contact with the inner side of the artery. The needle should be passed from within outward.

The *collateral circulation* will be carried on from above the ligature by (*a*) the internal pudic (from the internal iliac); (*b*) the gluteal and sciatic (from the same vessel); (*c*) the deep circumflex iliac, from the external iliac; (*d*) the obturator, and (*e*) the comes nervi ischiadici, anastomosing respectively with (*a*) the superficial and deep external pudic: (*b*) the circumflex and perforating arteries; (*c*) the external circumflex; (*d*) the internal circumflex; and (*e*) the perforating, all from either the common, superficial, or deep femoral.

Fig. 730.



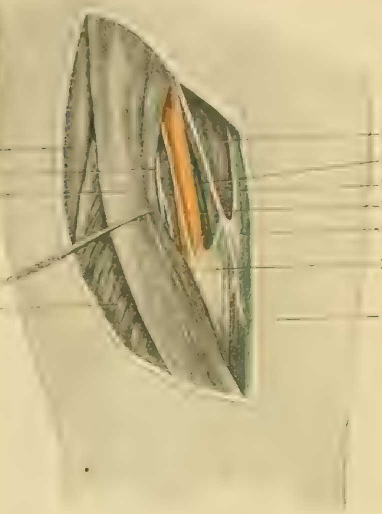
Superficial dissection of Scarpa's triangle, showing relations of femoral vessels.

2. At the apex of Scarpa's triangle an incision with its centre at the apex of the triangle is made on the line of the vessel, the thigh being abducted and rotated outward, the hip a little flexed, the knee well flexed, and the leg resting on its outer surface. Before reaching the deep fascia, the long saphenous vein or the external superficial femoral vein, may be met with and should be avoided. After opening the deep fascia the fibres of the inner edge of the sartorius should be exposed, and may be recognized by their oblique course. That muscle should be displaced outward, the vascular groove containing the vessel and some fatty areolar tissue identified, and the sheath exposed. The internal cutaneous branch of the anterior crural nerve in front, and the nerve to the vastus internus and the long saphenous nerve externally, should be avoided, and the sheath opened. The needle should be passed from without inward to avoid the vein, which here lies behind and to the outer side of the artery.

3. To reach the vessel in Hunter's canal, the limb being in the position above described, an incision is made on the line of the vessel extending from the apex of the triangle to about three inches above the internal condyle. The long saphenous vein should be avoided. The deep fascia is opened, and the outer edge of the sartorius identified. The only structure that could be mistaken for it is the vastus internus,

the fibres of which run obliquely outward instead of inward. The sartorius is displaced inward and the thigh more strongly abducted, when the tension on the adductor fibres—the adductor magnus and the lower edge of the adductor longus—will clearly define the lower—inner—border of Hunter's canal. The aponeurotic roof of the canal stretching across to the vastus internus is pierced by the internal saphenous nerve, which may be a useful guide. This aponeurosis is divided and the vessel exposed. The vein lies behind and somewhat to the outer side. The needle should be passed from without inward.

Fig. 731.



Dissection showing femoral vessels in Scarpa's triangle and disappearing in Hunter's canal.

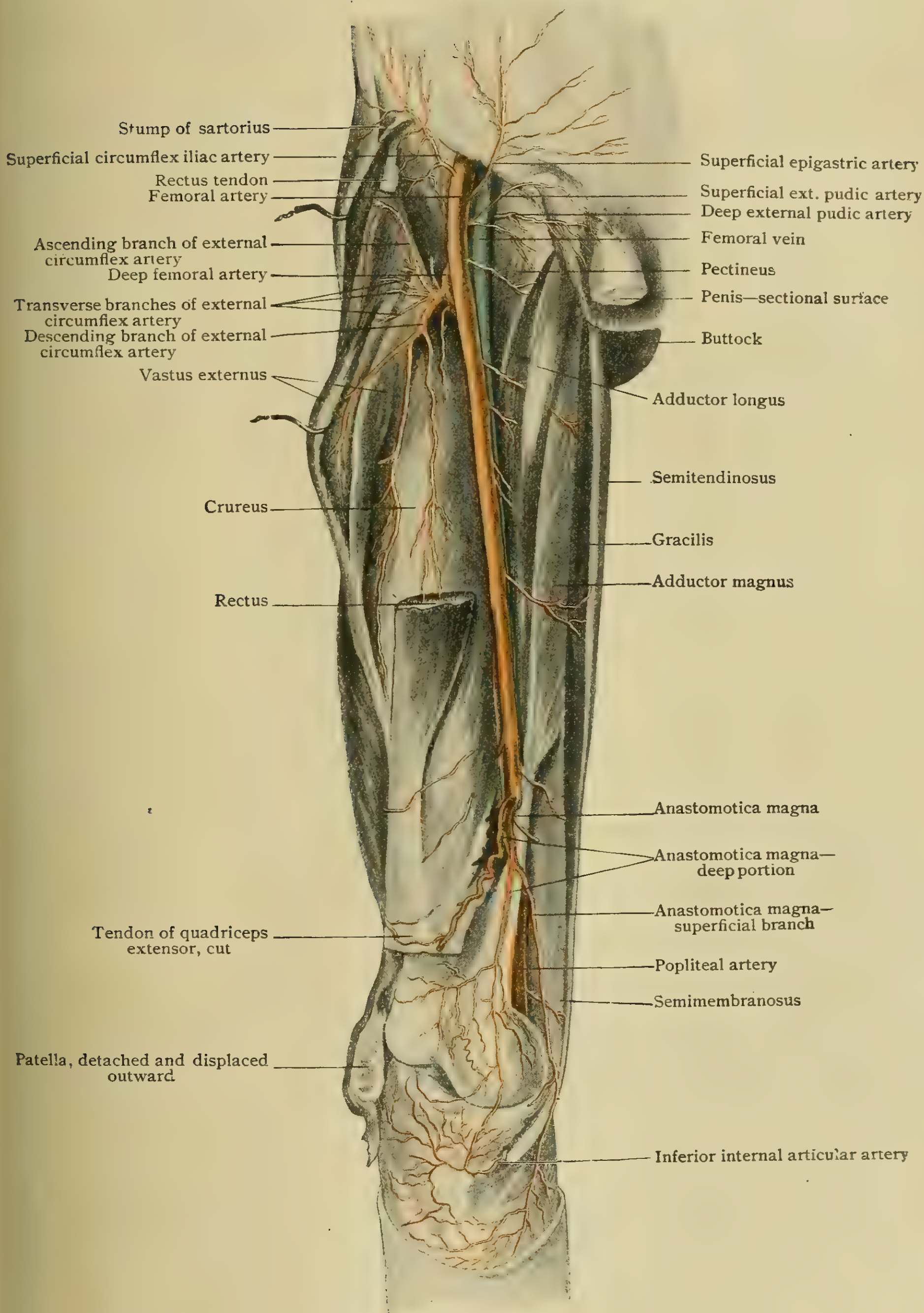
The *collateral circulation* after ligation of the superficial femoral is carried on from above by (*a*) the perforating and terminal branches of the profunda; and (*b*) the descending branch of the external circumflex anastomosing respectively with (*a*) the superior articular and muscular branches of the popliteal; and (*b*) the anastomotica magna and superior articular from below.

1. **The Superficial Epigastric Artery.**—The superficial epigastric artery (**a. epigastrica superficialis**) (Fig. 729) arises from the anterior surface of the femoral, about 1 cm. below Poupart's ligament. It is directed at first forward, but, after perforating the fascia lata or sometimes the cribriform fascia, it bends upward over Poupart's ligament and ascends between the superficial and deep layers of the superficial abdominal fascia to the neighborhood of the umbilicus. It gives branches to adjacent inguinal lymphatic nodes and to the integument, anastomosing with the cutaneous branches of the deep epigastric artery.

2. **The Superficial Circumflex Iliac Artery.**—The superficial circumflex iliac artery (**a. circumflexa ilium superficialis**) (Fig. 729) arises from the anterior surface of the femoral, a little below the superficial epigastric, or from a common trunk with that artery. It perforates the fascia lata or the cribriform fascia and is then directed laterally more or less parallel with Poupart's ligament, extending almost as far as the anterior superior spine of the ilium. It gives branches to the adjacent inguinal lymphatic nodes and to the sartorius muscle, and anastomoses with the cutaneous branches of the deep circumflex iliac.

3. **The Superficial External Pudic Artery.**—The superficial external pudic artery (**a. pudenda externa superficialis**) (Fig. 729) arises from the inner surface of the femoral artery and is directed inward and slightly upward towards the spine of the pubis. It pierces the cribriform fascia and, crossing over the spermatic cord or round ligament, sends branches to the integument above the pubes. It is then continued along the dorsal surface of the penis or clitoris, lateral and external to the dorsal artery of that organ, with which it anastomoses at the glans. It supplies branches to the integument of the penis and to the preputium clitoridis, and also gives branches to the scrotum or labium majus.

FIG. 732.



Arteries of front of thigh; deeper dissection.

4. **The Deep External Pudic Artery.**—The deep external pudic artery (**a. pudenda externa profunda**) (Fig. 732) arises from the inner surface of the femoral, either a little below the superficial external pudic or in common with that vessel. It passes medially beneath the fascia lata across the femoral vein and the pectineus and adductor longus muscles. It then pierces the fascia lata close to the ramus of the pubis and is distributed to the sides of the scrotum or labium majus, anastomosing with branches of the superficial external pudic and of the superficial perineal branch of the internal pudic.

5. **The Deep Femoral Artery.**—The deep femoral artery (**a. profunda femoris**) (Fig. 733) arises from the outer surface of the femoral, usually about 4 cm. below Poupart's ligament, and at first is directed downward parallel to the femoral and to the outer side of that vessel. It then bends medially and passes obliquely behind the femoral artery and vein, and on arriving at the upper border of the adductor longus, passes behind that vessel and is continued downward between it and the adductor magnus, rapidly diminishing in size. Finally it perforates the adductor magnus and terminates in branches to the lower portions of the hamstring muscles.

Relations.—At first the profunda lies alongside the femoral and is, like it, superficial, having in front of it only the fasciæ and integument, together with some branches of the anterior crural nerve. Later it lies behind the femoral artery and the femoral and profunda veins, and still later the adductor longus and the adductor magnus. Posteriorly it rests at first upon the ilio-psoas and then successively upon the pectineus, the adductor brevis, and the adductor magnus.

Branches.—The profunda femoris gives origin to the following branches: (1) the *external circumflex*, (2) the *internal circumflex*, (3) the three *perforating* arteries. The terminal portion of the profunda, after it has pierced the adductor magnus, is sometimes spoken of as the *fourth perforating* artery.

(*a*) The **external circumflex artery** (**a. circumflexa femoris lateralis**) is the largest of the branches of the profunda and arises from it a short distance beyond its origin. It is directed horizontally outward across Scarpa's triangle, resting upon the ilio-psoas muscle and passing between the superficial and deep branches of the anterior crural nerve. It then passes beneath the sartorius and rectus muscles and terminates by dividing into an ascending, a transverse, and a descending branch. The *ascending branch* passes upward and outward to beneath the tensor vaginæ femoris, running along the anterior trochanteric line of the femur, and terminates by anastomosing with the gluteal and the deep circumflex iliac arteries. It sends twigs to the neighboring muscles and to the hip-joint. The *transverse branch* is small and runs directly outward to below the greater trochanter, passing between the rectus and the crureus muscles and through the substance of the vastus lateralis. It unites with branches of the sciatic, internal circumflex, and first perforating arteries to form the *crucial anastomosis*. The *descending branch* runs downward beneath the rectus muscle, along with the nerve, to the vastus lateralis, and usually extends to the neighborhood of the knee-joint, where it anastomoses with the superior external branch of the popliteus and assists in the formation of the circumpatellar anastomosis. It gives branches to the rectus, crureus, and vastus lateralis.

(*b*) The **internal circumflex artery** (**a. circumflexa femoris medialis**) arises from the inner surface of the profunda, very nearly opposite the external circumflex. It passes over the surface of the ilio-psoas and beneath the pectineus to reach the anterior surface of the neck of the femur. It then crosses the upper portion of the adductor brevis and adductor magnus and passes along the lower border of the obturator externus and, finally, upon the anterior surface of the quadratus femoris, where it divides into its terminal branches.

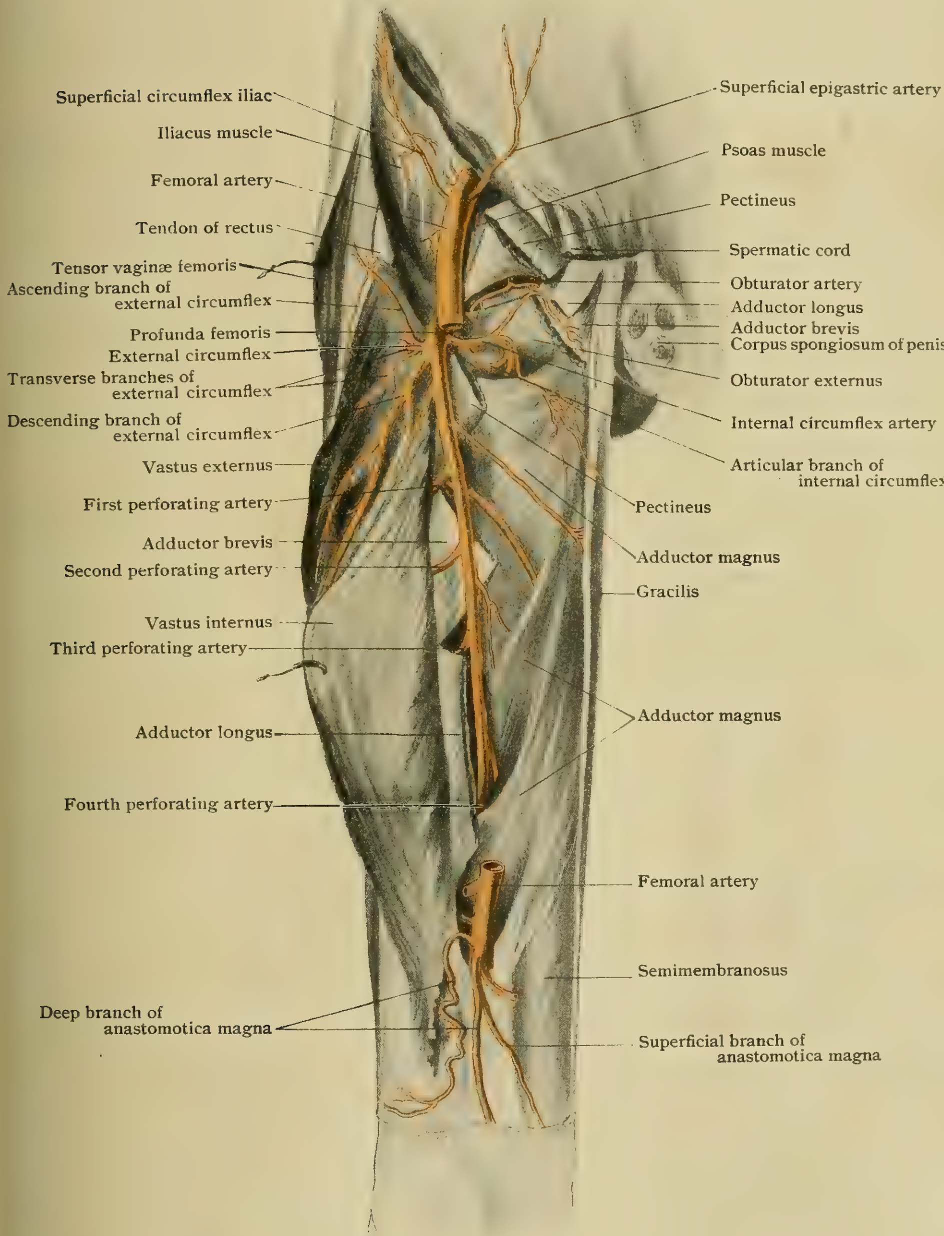
(*aa*) The **ascending branch** (**ramus ascendens**) passes upward towards the digital fossa of the femur, sending branches to the capsule of the hip-joint and anastomosing with the sciatic and external circumflex arteries.

(*bb*) The **descending branch** (**ramus descendens**) passes downward and curves around the lower border of the quadratus femoris to terminate in the upper portion of the hamstring muscles. This branch anastomoses with the sciatic, external circumflex, and first perforating vessels to form the crucial anastomosis. In addition the internal circumflex in its course sends **muscular branches** to the adjacent muscles and also an **articular branch** (**ramus acetabuli**) to the hip-joint.

(*c*) The three **perforating branches** arise in succession from the profunda and pass backward, curving around the inner surface of the femur. They perforate the adductor muscles close to the bone, and supply the hamstring muscles and the vastus externus, anastomosing with one another and with neighboring vessels.

(*aa*) The **first or superior perforating artery** (**a. perforans prima**) is generally the largest of the three, and arises just as the profunda passes behind the adductor longus. It either passes through the adductor brevis or between that muscle and the pectineus and pierces the adductor

FIG. 733.



Deep femoral artery and its branches.

magnus, and then divides into an ascending and a descending branch, the latter of which anastomoses with the ascending branch of the second perforating, while the former assists in the formation of the crucial anastomosis.

(*bb*) The **second or middle perforating artery** (a. perforans secunda) arises a little below the first and, after piercing the adductor brevis and the adductor magnus, divides into an ascending and a descending branch which anastomose respectively with the descending branch of the first and the ascending branch of the third perforating. A nutrient artery to the femur is usually given off from this vessel, although frequently it comes from the third perforating.

(*cc*) The **third or inferior perforating artery** (a. perforans tertia) arises usually on a level with the lower border of the adductor brevis. It pierces the adductor magnus and terminates, like the other perforating arteries, by dividing into an ascending and a descending branch. The ascending branch anastomoses with the descending branch of the second perforating, while the descending one anastomoses with branches from the terminal portion of the profunda. The nutrient artery to the femur is frequently given off by this branch.

Variations.—The variations of the profunda and its branches are somewhat numerous, and to a very considerable extent are largely associated with one another. In other words, there may be more or less dissociation of the various vessels of the profunda complex, one or other of them having an independent origin from the femoral, and, indeed, this process may occur to such an extent that a profunda femoris as a definite vessel can hardly be said to exist.

The point of origin of the profunda from the femoral is stated to be usually about 4 cm. distant from Poupart's ligament, but the figure must be taken as a general average from which there may be wide departures. Thus, in 430 limbs Quain found that the distance from Poupart's ligament of the origin of the profunda was between 2.5 and 5.1 cm. in 68 per cent., and of this number it was between 2.5 and 3.8 cm. in 42.6 per cent. It was distant less than 2.5 cm. in 24.6 per cent. of the limbs and more than 5.1 cm. in only 7.4 per cent. Quain's figures are as follows:

Origin at Poupart's ligament	7 cases.
0–1.3 cm. below Poupart's ligament	13 cases.
1.3–2.5 cm. below Poupart's ligament	86 cases.
2.5–3.8 cm. below Poupart's ligament	183 cases.
3.8–5.1 cm. below Poupart's ligament	109 cases.
5.1–6.3 cm. below Poupart's ligament	19 cases.
6.3–7.6 cm. below Poupart's ligament	12 cases.
11.6 cm. below Poupart's ligament	1 case.

Essentially similar results have been obtained by Srb and other observers, and it seems evident from the statistics that the origin of the profunda is more apt to be above than below the point taken as the average.

One or other of the circumflex arteries may arise independently from the femoral, this condition occurring somewhat more frequently in the case of the internal circumflex than in that of the outer one, and the point of origin of the independent vessel may be either above or below that of the profunda. When it is the internal circumflex which is the independent vessel, its origin is most frequently above that of the profunda; or perhaps it would be more correct to say that with an independent internal circumflex the origin of the profunda is apt to be somewhat below the typical point. With a high origin of the profunda, the external circumflex may be represented by two vessels, one of which arises from the profunda, while the accessory one springs from the femoral lower down. Occasionally both circumflexes may arise independently from the femoral, the profunda in such cases having usually a low origin, and one or other of the perforating arteries may arise from the circumflexes. An extreme case of this nature, representing an almost complete dissociation of the profunda, has been described by Ruge, (Fig. 734) in which the superior perforating arises from the internal circumflex and the middle one from the external circumflex, what may be termed the profunda arising 9.7 cm. below Poupart's ligament and giving off only the inferior perforating.

FIG. 734.

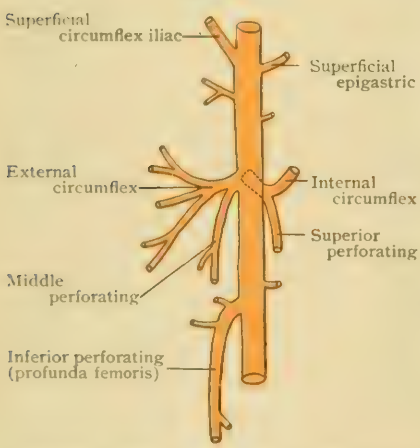


Diagram showing almost complete dissociation of profunda femoris. (*Ruge*).

The internal circumflex may be very much reduced in size or even absent, its territory being supplied by branches from the obturator artery. Occasionally, although rarely, one or other of the perforating branches arises directly from the femoral, and a similar origin has also been observed for the descending branch of the external circumflex.

6. **The Muscular Branches.**—The muscular branches (**rami musculares**) of the femoral artery are rather numerous and are distributed to all the muscles upon the front of the thigh. They are variable in number and position and do not call for any special description.

7. **The Anastomotica Magna.**—The anastomotica magna (**a. genu suprema**) (Fig. 733) arises from the femoral, just before it passes through the adductor magnus. It passes downward a short distance in front of the adductor magnus and divides into two branches, a superficial and a deep.

Branches.—(*a*) The **superficial branch** (**ramus saphenus**) follows the course of the long saphenous nerve and, perforating with it the crural fascia, is supplied to the integument over the inner side of the knee and the upper portion of the leg. It anastomoses with the inferior internal articular branch of the popliteal, then entering into the formation of the circumpatellar anastomosis.

(*b*) The **deep branch** (**ramus musculo-articularis**) enters the substance of the vastus internus and passes downward to take part in the formation of the circumpatellar plexus, also sending branches to the capsule of the knee-joint.

Variations.—The anastomotica magna is occasionally given off from the upper portion of the popliteal artery. Occasionally it is continued some distance down the leg with the long saphenous nerve, representing in such cases more perfectly the original saphenous artery (page 849); or this vessel may be indicated by a series of anastomoses which accompany the nerve and vein and begin with the superficial branch of the anastomotica.

Anastomoses of the Femoral Artery.—In the case of obliteration of the external iliac artery, blood may reach the femoral by means of the anastomoses of the iliac arteries already noted (page 821), and, in addition, by way of the anastomoses between the superficial and deep epigastrics and between the superficial circumflex iliac artery and the deep vessel of the same name and the gluteal. The anastomoses between the external and internal pudics would also assist.

If the obliteration of the femoral artery be above the origin of the profunda femoris, a collateral circulation may be established by the union of the branches of that vessel with the sciatic in the crucial anastomosis and also by the communication existing between the external circumflex and the gluteal and the deep circumflex iliac.

If the obliteration be below the origin of the profunda, circulation will be maintained through the anastomoses around the knee-joint, in which the descending branch of the external circumflex and the terminal portion of the profunda, on the one hand, and the anastomotica magna, on the other, participate.

THE POPLITEAL ARTERY.

The popliteal artery (**a. poplitea**) (Fig. 736) is the continuation of the femoral, and extends from the point where the latter pierces the adductor magnus to the lower border of the popliteus muscle, where it divides into the anterior and posterior tibial arteries. Its course is at first downward and slightly outward, but it soon becomes almost vertical, corresponding practically with the long axis of the popliteal space.

Relations.—*Anteriorly*, the popliteal artery is in relation to the posterior surface of the lower part of the femur, from which it is separated, however, by a layer of adipose tissue. Lower down it rests upon the posterior ligament of the knee-joint, and still lower upon the fascia covering the posterior surface of the popliteus muscle. *Posteriorly*, it is somewhat overlapped in the upper part of its course by the border of the semimembranosus, and below by the inner head of the gastrocnemius. In its passage through the popliteal space, however, it is covered only by the integument and fasciæ, beneath which is a considerable amount of fatty tissue. About the middle of its course it is crossed obliquely from without inward by the internal popliteal nerve, and throughout its entire length it has resting upon and firmly adherent to it the popliteal vein, which lies, however, slightly to its outer side above and to its inner side below. *Internally*, it is in relation from above downward with the semimembranosus, the internal condyle of the femur, the internal popliteal nerve, and the inner head of the gastrocnemius, and *externally* with the internal popliteal nerve, the external condyle of the femur, the outer head of the gastrocnemius, and the plantaris.

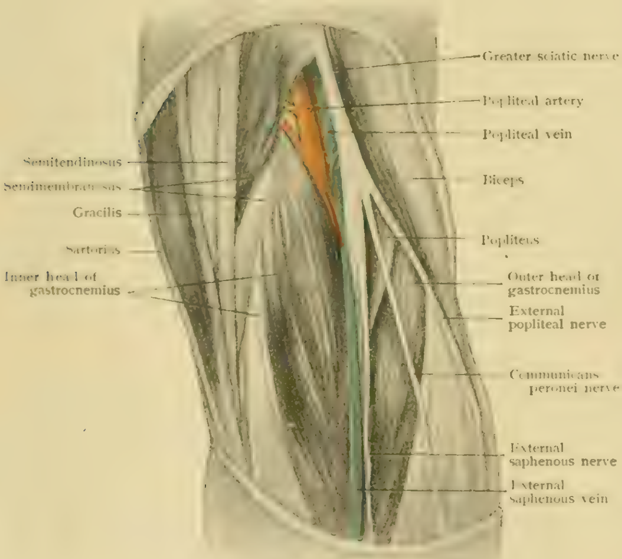
Branches.—The branches which arise from the popliteal artery are all small and may be arranged in three groups: (1) *muscular*, (2) *articular*, (3) *cutaneous*.

Variations.—The popliteal artery occasionally divides into the tibial arteries above the upper border of the popliteus muscle, and more rarely the division is delayed until the artery has reached a point almost half-way down the leg.

Practical Considerations.—The popliteal artery is rarely wounded because of its protected position on the posterior aspect of the limb and in the hollow of the ham. Its upper portion is overlapped by the outer border of the semimembranosus muscle, and its lower portion by the inner head of the gastrocnemius; the intermediate portion, covered only by skin, fascia, and areolo-fatty tissue, is very deeply placed and is not more than an inch in length. It may be torn in luxation of the knee, or wounded in fracture of the lower end of the femur, or during certain operations, as osteotomy of the femur for genu valgum. Laceration or wound of this vessel is more dangerous than a corresponding injury to the brachial at the bend of the elbow, because of the greater proximity—in the case of the popliteal—of the branches on which the chief anastomotic supply depends; and because of the unyielding character of the walls of the space in which the effused blood is confined.

Aneurism of the popliteal artery comes next in frequency to aneurism of the thoracic aorta. This is due (*a*) to the frequent minor strains occurring during flexion and extension of the knee. If extreme, the former movement bends the artery at such an acute angle that the flow of blood through it is arrested and the pressure above this point greatly increased; and the latter may so stretch the vessel longitudinally that if its elasticity is at all diminished by atheromatous changes the inner and middle coats are thinned or ruptured. (*b*) The lack of muscular support which the artery—surrounded by loose cellular tissue—receives also favors the development of aneurism. (*c*) The artery is said to be unusually liable to atheromatous degeneration. (*d*) It divides a short distance below into two vessels, thus increasing the blood-pressure above the bifurcation. (*e*) Its course is curved (like that of the aortic arch), and hence the pressure is irregularly distributed. (*f*) The tendinous opening in the adductor magnus, through which the vessel runs, constricts it slightly at each pulse-beat and tends—as in the case of the abdominal aorta below the hiatus aorticus—to produce a little dilatation below that level. As both these vessels have been said to be especially weak in these regions, it may be possible that some trifling but oft-repeated interference with the vasa vasorum favors degenerative changes by slightly diminishing the blood-supply to the vessel walls.

FIG. 735.



Dissection of right popliteal region, showing relation of vessels and nerves.

Aneurism may occur suddenly, with a sensation resembling that produced by a blow with a whip. It may develop slowly, and, if it takes a forward direction, with symptoms simulating rheumatism on account of the pressure upon the posterior ligament of the knee-joint—*i.e.*, dull pain, stiffness, semi-flexion of the knee, inability to extend the joint freely. If it develops in the opposite direction, the absence of resistance causes the early appearance of a characteristic pulsating tumor with bruit and the usual signs of aneurism. It should not be confused with an enlarged bursa (page 647), the subject of transmitted pulsation, or with tumor or abscess overlying

the artery and similarly influenced. Ultimately there is apt to be œdema of the leg from interference with the venous circulation, or erosion of the posterior lower surface of the femur, or great pain with weakness of the leg from pressure on the internal popliteal nerve, or even moist gangrene if the aneurism has leaked or burst and the venous current has been cut off by the pressure of the effused blood confined for a time within narrow limits and under great pressure by the fascia of the region (page 646).

Compression of the popliteal may be effected directly at its upper end by pressure forward, so that it is flattened out against the femur, only a little fatty connective tissue intervening. It is almost impossible, however, to avoid including the thick-walled vein which is nearer the surface and very closely attached to the artery. Compression is therefore almost invariably applied to the common femoral (page 824). On account of the shortness of the popliteal—and the consequent proximity of a ligature to the diseased portion, if the vessel itself is tied—the superficial femoral at the point of election—the apex of Scarpa's triangle—is usually selected for ligation when that becomes necessary.

Ligation of the popliteal artery is effected at either : (1) its upper, or (2) its lower third, the depth of the middle portion and the density of the lateral fascial border of the space in which it lies rendering it unsuitable for operation.

1. The patient being prone with the leg extended, an incision is made along the external border of the semimembranosus muscle, beginning at the junction of the middle and lower thirds of the thigh. The skin and fascia and some fatty tissue having been divided, the muscle is drawn inward, and the vessel will be found with the internal popliteal nerve external to it and much more superficial, and the vein external and behind it,—*i.e.*, nearer the surface of the popliteal space—and closely adherent. The needle is passed from without inward.

2. An incision is made beginning opposite the line of the articulation a little external to the middle of the popliteal space, the inner head of the gastrocnemius being slightly larger than the outer head. The external saphenous vein lying in the superficial fascia is drawn to one side, the fascia is divided, and the two heads of the gastrocnemius are exposed and separated with the finger, the knee being a little flexed so as to relax them. At the bottom of the interval between them will be found the nerve and vein lying to the inner side of the artery and somewhat superficial to it. The needle is passed from within outward.

The *collateral circulation* is carried on from above the ligature by means of (*a*) the superior articulars ; (*b*) the anastomotica magna ; (*c*) the descending branch of the external circumflex and the terminal portion of the profunda anastomosing respectively with (*a*) the inferior articulars ; (*b*) the tibial recurrent ; and (*c*) the superior fibular and branches of the popliteal. The rete patellæ takes part in this anastomosis.

1. **The Muscular Branches.**—These (Fig. 736) are arranged in two groups, and are supplied to the muscles which bound the popliteal space. The *superior group* consists of a variable number of small vessels which pass to the biceps, semimembranosus, and semitendinosus, while the *inferior group* is composed of some small branches which pass to the popliteus muscle, and two larger vessels, the largest of all the vessels which arise from the popliteal, which pass respectively to the inner and outer heads of the gastrocnemius, and are termed the *sural arteries* (**aa. surales**). They arise just as the popliteal is passing beneath the inner head of the gastrocnemius.

2. **The Articular Branches.**—These (Fig. 736) are five in number, four being arranged in pairs, two above and two below, while the fifth is unpaired or azygos. The paired branches wind around the femur and the capsule of the knee-joint towards the front, where they anastomose with one another and with adjacent vessels to form a rich circumpatellar anastomosis. They give off branches to the capsule of the knee-joint and also to the neighboring muscles.

(*a* and *b*) The **internal and external superior articular branches** (**aa. genu superior medialis et lateralis**) arise opposite each other and pass transversely above the corresponding heads of the gastrocnemius. The external one then passes beneath the biceps and winds around the femur

above its external condyle, embedded in the substance of the vastus externus, dividing finally into branches which take part in the formation of the circumpatellar anastomoses. The termination of the internal branch is similar, and its course is beneath the semimembranosus and through the tendon of the adductor magnus into the substance of the vastus internus.

(*c*) The **internal inferior articular branch** (**a. genu inferior medialis**) arises about opposite or a little above the line of the tibio-femoral articulation and courses downward and inward over the surface of the popliteal muscle, beneath the inner head of the gastrocnemius. It passes beneath the internal lateral ligament of the knee-joint and winds around the tuberosity of the tibia to join the circumpatellar anastomosis.

(*d*) The **external inferior articular branch** (**a. genu inferior lateralis**) arises a little lower down than its fellow and passes almost transversely outward, at first beneath the external head of the gastrocnemius and the plantaris, and winds around the outer tuberosity of the tibia, beneath the long internal lateral ligament of the knee-joint, to join the circumpatellar anastomosis.

(*e*) The **azygos articular branch** (**a. genu media**) is the smallest of all the articular branches. It arises either from the anterior surface of the popliteal or from the external superior articular branch, and pierces the posterior ligament of the knee-joint to be distributed to the crucial, mucous, and alar ligaments.

The **circumpatellar anastomosis** (**rete patellae**) (Fig. 732) is a rich net-work of vessels which occurs in the superficial fascia surrounding the patella, and from which branches are sent to the patella, the capsule of the knee-joint, and the neighboring muscles. The following vessels take part in its formation. From above, the anastomotica magna from the femoral and the descending branch of the external circumflex; from the sides, the internal and external superior and the internal and external inferior articular branches of the popliteal and the muscular branches of the same artery; and from below, the anterior tibial recurrent.

3. **The Cutaneous Branches.**—These are variable in origin and number and are distributed to the integument covering the popliteal space and the upper part of the calf of the leg. One of them occasionally attains a considerable size and is termed the *posterior saphenous artery*. It accompanies the short saphenous vein down the back of the crus, sending off branches to the adjacent integument.

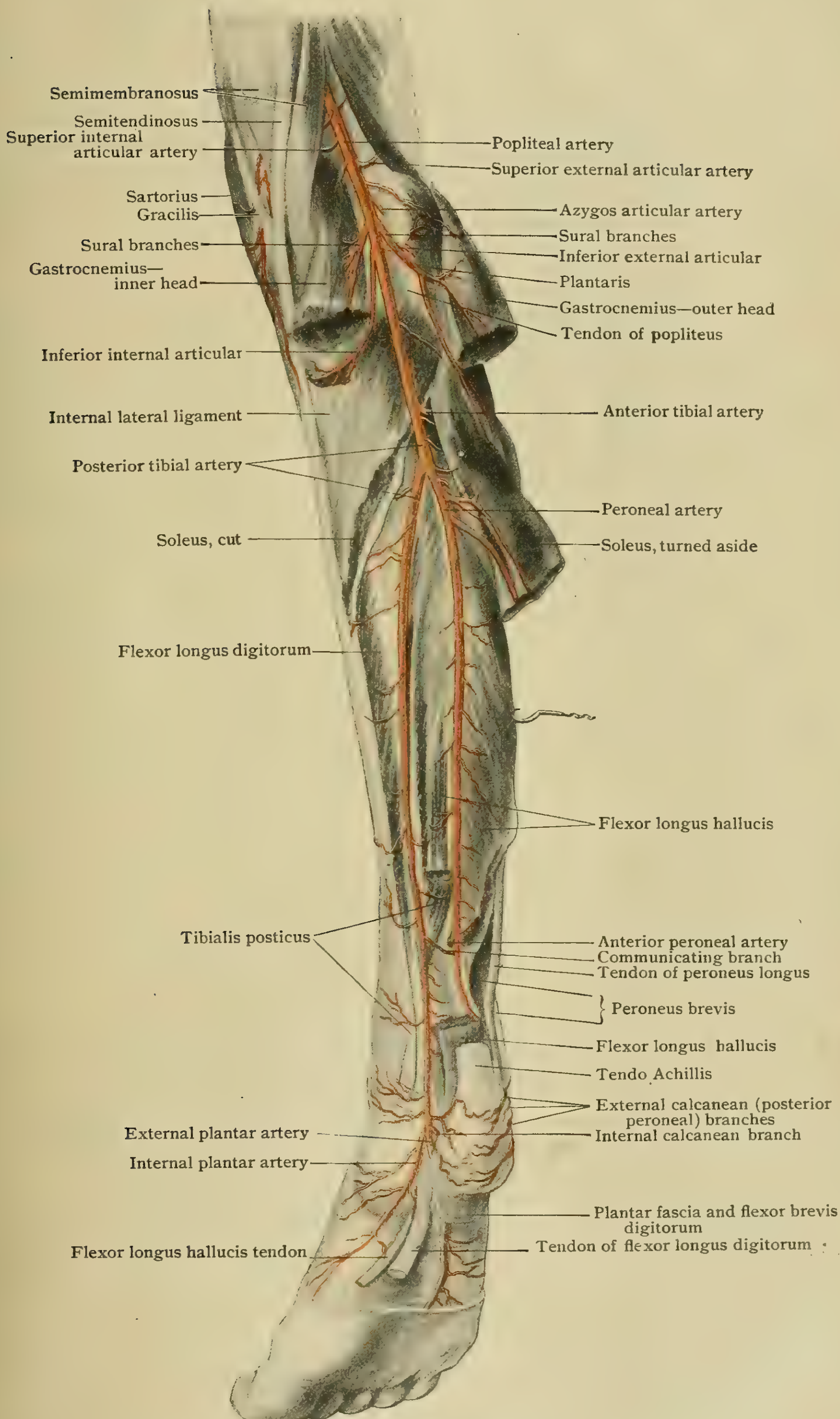
The Collateral Circulation of the Popliteal Artery.—The passage of blood to the leg after ligation of the popliteal artery is effected by means of the rich anastomosis which exists around the knee-joint, and in which the branches of the popliteal take part. In addition to these, however, it also receives from above the anastomotica magna, the descending branch of the external circumflex, and the terminal portion of the profunda artery, while there pass to it from below the superior fibular and the anterior and posterior tibial recurrent arteries.

THE POSTERIOR TIBIAL ARTERY.

The posterior tibial artery (**a. tibialis posterior**) (Fig. 736) is the direct continuation of the popliteal down the posterior surface of the leg. It begins at the bifurcation of the popliteal at the lower border of the popliteus muscle and passes almost vertically downward, under cover of the more superficial muscles of the calf, to the groove between the inner malleolus and the os calcis, where, opposite the tip of the malleolus, it terminates by dividing into the internal and external plantar arteries. Its course may be indicated by a line drawn from the centre of the popliteal space to a point midway between the inner malleolus and the os calcis.

Relations.—*Anteriorly*, the artery rests in succession, from above downward, upon the tibialis posticus, the flexor longus digitorum, the posterior surface of the lower part of the tibia, and the internal lateral ligament of the ankle-joint. It is closely bound down to the muscles upon which it rests by the layer of the deep fascia which covers them, the thickness and density of this fascia increasing towards the lower part of the leg. *Posteriorly*, it is covered by the soleus and gastrocnemius throughout the greater part of its course, but in the lower third of the leg it is superficial, being covered only by the skin and fasciæ, except just before its termination, where it lies beneath the internal annular ligament and the origin of the abductor hallucis. A short distance below its commencement it is crossed obliquely, from within outward, by the posterior tibial nerve. *Internally*, it is in relation with the posterior tibial nerve for a short distance above, and in the malleolar groove it has

FIG. 736.



Arteries of posterior surface of right leg.

internally and in front of it the tendon of the flexor longus digitorum, and internal to that the tendon of the tibialis posticus. *Externally*, the posterior tibial nerve accompanies it throughout the greater portion of its course, and at the ankle-joint the nerve lies external and posterior to the artery, between it and the tendon of the flexor longus hallucis. The artery is accompanied throughout its course by two venæ comites which lie respectively to its outer and inner side.

Branches.—In addition to numerous *muscular branches* which are distributed to the neighboring muscles, and cutaneous branches to the inner and posterior surfaces of the leg, the posterior tibial gives origin to (1) a *nutrient branch* to the tibia, (2) the *peroneal artery*, (3) a *communicating branch*, (4) an *internal malleolar branch*, (5) an *internal calcaneal* and the two terminal branches, (6) the *internal*, and (7) the *external plantar arteries*.

Variations.—Although apparently the principal artery of the flexor surface of the leg and the direct continuation of the popliteal, developmentally the posterior tibial is a secondary vessel, the original main vessel being the peroneal. The history of the posterior tibial seems to have been somewhat as follows. The saphenous artery, whose origin has been mentioned in connection with the variations of the femoral artery (page 823), in the lower part of the leg winds around to the posterior surface and passes behind the internal malleolus, where it terminates by dividing into the plantar arteries. From the upper part of the peroneal artery a branch arises which passes down the tibial side of the leg, beneath the superficial flexor muscles, and at the internal malleolus anastomoses with the saphenous. This vessel is the posterior tibial, and, its calibre enlarging, exceeds that of the peroneal, which thus sinks to the rank of a branch of the artery to which it gave birth. A reason for this increase of calibre in the posterior tibial is to be found in the degeneration of the saphenous artery (page 849), whereby the tibial becomes the channel of supply for the plantar arteries, which seem to be its continuation.

The majority of the principal variations of the posterior tibial are readily explained in the light of such a history. Thus there may be no posterior tibial, or it may be represented by a small vessel whose distribution is confined to the upper part of the leg. In such a case, as the saphenous artery degenerates, anastomoses between it and the terminal portion of the peroneal may enlarge so that the plantar arteries come to take their origin from that vessel. Or, again, the development of the posterior tibial may proceed normally, but the lower portion of the saphenous may not degenerate completely, but persists, as has been observed, as a branch of the tibial, passing upward upon the leg in company with the long saphenous nerve.

Other variations of the posterior tibial which have been observed, however, cannot apparently be explained as resulting from modifications of the normal course of development, but are rather to be regarded as progressive variations due to the enlargement of what are usually more or less insignificant anastomoses. Of this nature is the origin from the posterior tibial, at about the middle of the leg, of a branch which pierces the interosseous membrane and divides into an ascending and a descending branch, which together represent the anterior tibial artery. Or, again, the posterior tibial has been observed to perforate the lower part of the interosseous membrane and to be continued down the dorsum of the foot as the dorsalis pedis artery, the plantar arteries arising from the peroneal. Occasionally, also, the posterior tibial may terminate by inosculating with the peroneal, probably by the enlargement of the communicating branch, the peroneal in this case also giving rise to the plantar arteries.

The high and low origins of the posterior tibial have already been mentioned in connection with the variations of the popliteal (page 831).

Practical Considerations.—The posterior tibial artery on account of its deep position beneath the large superficial calf muscles is rarely wounded and, by reason of the support which it receives in its upper two-thirds from those muscles and the deeper muscular layer on which it lies, and in its lower third from the dense fascia covering it, it is seldom the subject of aneurism. Except for a short portion of its course immediately above the ankle, it is separated from the tibia by the deep calf muscles, and is therefore not often involved in fractures of that bone.

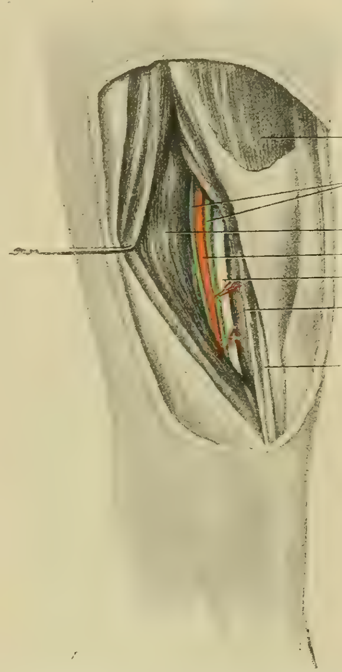
The bifurcation of the popliteal is not infrequently the region at which an embolus carried down from the popliteal is arrested, and such a clot may block both the tibial arteries. Their free anastomosis prevents gangrene if only one of them is occluded; but if both are involved, and especially if the succeeding additions to the clot invade the anterior tibial recurrent—interfering with anastomosis from above—gangrene almost certainly follows.

Compression of the posterior tibial is scarcely possible above its lower third. Above the ankle and behind the inner malleolus it may be flattened against the tibia by pressure directed outward and a little forward.

Ligation of the posterior tibial may be done at any part of its course, but in its upper third is an operation of some difficulty.

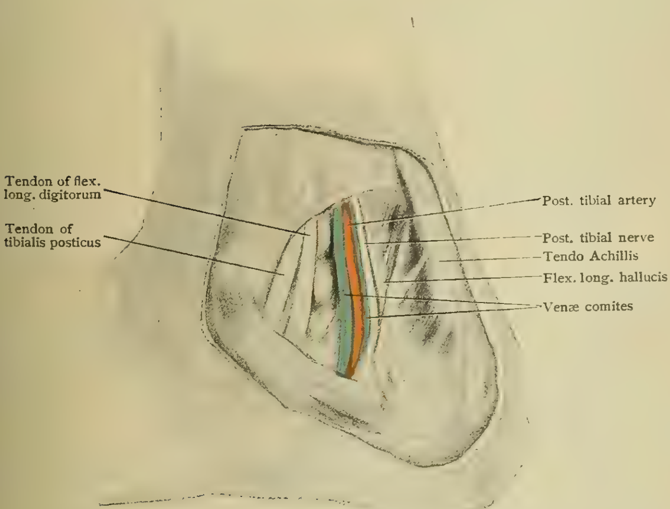
1. The artery is best approached from the inner side of the leg. The leg being flexed, the limb is laid on its outer side, and an incision three and a half or four inches in length is made along the inner margin of the tibia, beginning two and a half inches from the upper end of that bone. The skin being divided, care must be exercised in opening the superficial fascia not to injure the internal saphenous vein or nerve, both of which lie directly in the track of the wound. These structures being displaced, the deep fascia must be slit up to the full extent of the incision. It should also be cut transversely, so as to allow a freer access to the intermuscular parts. The next step consists in detaching the origin of the soleus muscle from the tibia. It is at this stage of the operation that one of two errors is often committed,—the intermuscular space between the inner head of the gastrocnemius and the soleus muscle is opened, or all the muscular tissue is separated from the bone, the tibialis posticus muscle being raised along with the soleus. The first mistake leads the operator above the vessel and the second leads him underneath. There is, however, a guide which will afford important assistance. If the soleus has been properly detached and raised, its under surface will present a white, shining sheet of tendinous material, beneath which will be seen a layer of fascia (intermuscular) covering the tibialis posticus muscle. If search is now made externally and towards the middle of the leg, the artery will be found covered by the intermuscular fascia, the nerve lying to its outer side. After the vessel has been separated from the investing connective tissue and the accompanying veins, the needle must be passed from without inward (Agnew).

FIG. 737.



Dissection of back of right leg, showing relations of posterior tibial vessels and nerve; gastrocnemius and soleus muscles have been cut and drawn aside.

FIG. 738.



Dissection of inner side of right ankle, showing relation of tendons, vessels and nerves as they pass between calcanium and internal malleolus.

2. At the middle third the artery is reached through an incision parallel with the inner edge of the tibia and a half inch from its border. Avoiding the saphenous vein and nerve, the superficial fascia and the deep fascia (with its fibres running transversely) are

divided in the line of the skin wound, the inner margin of the soleus displaced outward, and the vessel, with its venæ comites, exposed, the posterior tibial nerve lying to its outer side. A little lower—*i.e.*, in the lower third of the leg—the incision should be made midway between the inner edge of the tibia and the inner edge of the tendo Achillis, and the artery will be found lying on the fibres of the flexor longus digitorum, the tendon to the inner side, and the nerve external.

3. To ligate the vessel at the inside of the ankle the incision should be semilunar in shape, parallel with the margin of the inner malleolus, and about half-way between it and the margin of the tendo Achillis. After dividing the deep fascia—internal annular ligament—the artery will be found, with its accompanying veins, lying between the flexor longus digitorum and tibialis posticus tendons on the inside —each in a separate synovial sheath and the latter near the malleolus—and the nerve and flexor longus pollicis tendon on the outside. The sheaths of these tendons should not be opened.

The *collateral circulation* is carried on from above the ligature by (*a*) the anterior and posterior peroneal arteries and their muscular and communicating branches; (*b*) the external malleolar branch of the anterior tibial; (*c*) the internal malleolar (anterior tibial); (*d*) the *dorsalis* pedis. Anastomosing respectively with (*a*) the muscular branches and the communicating branch of the posterior tibial; (*b*) the external plantar branch of the posterior tibial; (*c*) the internal malleolar (posterior tibial); and (*d*) the internal and external plantars.

1. **The Nutrient Artery.**—The nutrient artery to the tibia (**a. nutritia tibiae**) may arise from the posterior tibial, either above or below the origin of the peroneal artery, or sometimes it arises from that vessel. It pierces the tibialis posticus and enters the nutrient foramen on the posterior surface of the tibia, sending off, before it does so, some small muscular branches.

2. **The Peroneal Artery.**—The peroneal artery (**a. peronaea**) (Fig. 736) is by far the largest of the collateral branches of the posterior tibial. It arises about 2.5 cm. below the lower border of the popliteus muscle and is at first directed outward and downward towards the fibula, and then passes vertically downward along the inner surface of that bone to a point about 2.5 cm. above the ankle-joint, where it terminates by dividing into the anterior and posterior peroneal arteries.

Relations.—In the upper part of its course it is covered posteriorly by the soleus, lying between that muscle and the tibialis posticus. Lower down it passes beneath the flexor longus hallucis or else traverses the substance of that muscle, and just before its termination it emerges from beneath the muscle and becomes superficial. It is accompanied by two venæ comites.

Branches.—In addition to numerous *muscular branches* to the neighboring muscles and *cutaneous branches* to the integument of the outer border of the crus, the peroneal artery gives off the following vessels:

(*a*) The **nutrient artery to the fibula** (**a. nutritiae fibulae**) enters the nutrient foramen of that bone.

(*b*) The **communicating branch** (**ramus communicans**) passes inward over the lower end of the tibia and beneath the tendo Achillis, a short distance above the terminal bifurcation of the peroneal. It inosculates with the communicating branch of the posterior tibial.

(*c*) The **anterior peroneal artery** (**ramus perforans**) is one of the terminal branches of the peroneal. It passes directly forward and, perforating the interosseous membrane, bends downward over the ankle-joint to the dorsum of the foot. It sends branches to the ankle-joint and to the inferior tibio-fibular articulation, as well as to the peroneus tertius muscle, beneath which it passes, and terminates by anastomosing with the tarsal and metatarsal branches of the dorsalis pedis and with the external plantar artery upon the side of the foot.

(*d*) The **posterior peroneal artery** is the other terminal branch of the peroneal, of which it is the direct continuation. It gives origin to the *external calcaneal branch* which ramifies over the outer surface of the os calcis and terminates by anastomosing with the internal calcaneal branch of the posterior tibial artery and with the tarsal and metatarsal branches of the dorsalis pedis.

Variations.—The peroneal artery is exceedingly subject to variation. It is rarely absent, but not infrequently it terminates over the outer malleolus, its lower portion being given off from a branch which passes across from the posterior tibial and represents the enlarged anastomosis

of the posterior tibial and peroneal communicating branches. Conversely, when the lower portion of the posterior tibial is wanting, it may be replaced by the peroneal, which then gives rise to the plantar arteries. Occasionally the peroneal is larger than usual, and may give origin to the anterior tibial artery, and it may give off the nutrient artery for the tibia.

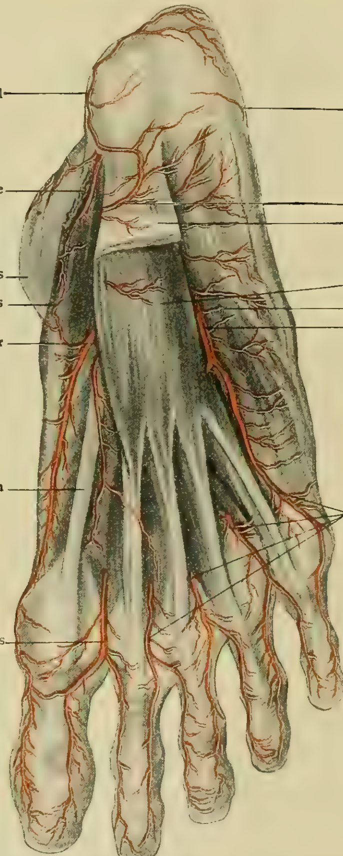
The anterior peroneal artery is sometimes absent, but more frequently it is larger than usual and inosculates with the anterior tibial. Occasionally the lower portion of this latter vessel is wanting, and the anterior peroneal may then take its place, being continued downward upon the dorsum of the foot as the dorsalis pedis and giving off the branches which normally arise from that vessel.

3. **The Communicating Artery.**—The communicating artery (**r. communicans**) (Fig. 736) extends transversely outward across the posterior surface of the tibia, beneath the tendon of the flexor longus hallucis and the tendo Achillis, and anastomoses with the communicating branch of the peroneal.

4. **The Internal Malleolar Artery.**—The internal malleolar artery (**a. malleolaris posterior medialis**) (Fig. 740) passes directly inward, beneath the tendons of the flexor longus digitorum and tibialis posticus, to ramify over the internal surface of the inner malleolus, anastomosing with the internal malleolar branch of the anterior tibial artery.

5. **The Internal Calcaneal Artery.**—The internal calcaneal artery (**ramus calcanei medialis**) (Fig. 736) arises from the lower part of the posterior tibial, just before it divides into the two plantar vessels. It is frequently represented by several branches which descend along the inner side of the tuberosity of the os calcis, supplying the neighboring parts of the integument and anastomosing with branches of the internal malleolar and posterior peroneal arteries.

Fig. 739.



Arteries of plantar surface of right foot; superficial dissection.

6. **The Internal Plantar Artery.**—The internal plantar artery (**a. plantaris medialis**) (Fig. 740) is the smaller of the two terminal branches of the posterior tibial. It arises in the groove between the internal malleolus and the os calcis and is directed at first downward and forward, under cover of the abductor hallucis, and then forward along the inner border of the foot, between the abductor hallucis and the flexor brevis digitorum, terminating opposite the head of the first metatarsal bone by anastomosing with one or other of the two branches distributed to the plantar surface of the great toe.

Branches.—In its course it gives off *muscular branches* to the abductor hallucis and the flexor brevis digitorum, *cutaneous branches* to the integument over the inner border of the foot, and *articular branches* to the neighboring tarsal joints. In addition, it usually gives off near its

origin a larger branch, the *anastomotic branch*, which passes beneath the abductor hallucis to gain the upper border of that muscle, along which it courses forward, giving off numerous branches to the abductor and the adjacent integument and anastomosing with the tarsal and metatarsal branches of the dorsalis pedis. More distally it gives off from its outer surface a varying number of slender *superficial digital* branches, which pass obliquely forward and outward across the sole of the foot to anastomose with one or more of the plantar interosseous branches from the plantar arch.

Variations.—Occasionally the superficial digital branches of the internal plantar arise from a common stem which anastomoses with a branch from the external plantar to form a *superficial plantar arch* beneath the superficial fascia. This is the equivalent of the superficial palmar arch of the hand.

7. **The External Plantar Artery.**—The external plantar artery (**a. plantaris lateralis**) (Fig. 740) is the larger of the terminal branches of the posterior tibial. It passes forward and outward across the sole of the foot, at first between the flexor brevis digitorum and the flexor accessorius, and then in the interval between the flexor brevis digitorum and the abductor minimi digiti. Opposite the base of the fifth metatarsal bone it turns somewhat abruptly inward and again crosses the sole of the foot, forming the **plantar arch** (**arcus plantaris**), which terminates at the proximal end of the first intermetatarsal space by uniting with the communicating branch from the dorsalis pedis.

Relations.—In the first part of its course the external plantar lies beneath the abductor hallucis and the flexor brevis digitorum, but as it approaches the fifth metatarsal it becomes more superficial, being covered only by the skin and the superficial and plantar fasciæ. It rests upon the flexor accessorius and the flexor brevis minimi digiti, and is accompanied by the external plantar nerve.

The plantar arch, on the contrary, occupies a much deeper position. It passes beneath the tendons of the flexor longus digitorum, the lumbricales, and the oblique portion of the adductor hallucis, resting upon the proximal ends of the second, third, and fourth metatarsals and upon the interosseous muscles which occur between those bones.

Branches.—The external plantar artery gives rise to (*a*) numerous **muscular branches** which supply the various muscles of the plantar surface of the foot, and in its first part to

(*b*) **Cutaneous branches** which supply the skin over the sole and outer border of the foot, some of them forming anastomoses with branches of the tarsal and metatarsal branches of the dorsalis pedis. In addition, there are given off from the first portion of the artery—

(*c*) **Calcaneal branches**, one or more in number, which arise near the commencement of the external plantar and ramify over the inner surface of the os calcis, anastomosing with the internal calcaneal branches of the posterior tibial.

From the plantar arch a number of vessels are given off.

(*d*) The **articulating branches** are given off from the posterior or concave surface of the arch and supply the tarsal articulations.

(*e*) The **posterior perforating branches**, four in number, arise either from the plantar arch or from the plantar digital branches of the fourth intermetatarsal space. They ascend in the intermetarsal spaces between the heads of the dorsal interosseous muscles and terminate by inosculating with the first, second, and third dorsal interosseous arteries. The branch which passes through the first intermetatarsal space is much larger than the rest and inosculates with the dorsalis pedis artery; it is sometimes regarded as the terminal branch of that vessel.

(*f*) The **plantar interosseous arteries** (**aa. metatarsae plantares**) are five in number, and are usually numbered in succession from the outer side of the foot inward,—that is to say, in the opposite direction to the intermetatarsal spaces in which they lie. The *first* arises just where the external plantar artery is bending inward to form the plantar arch and passes forward along the inner border of the abductor minimi digiti, later crossing over the flexor brevis minimi digiti to reach the outer surface of the little toe, along which it runs.

The *second*, *third*, and *fourth* plantar interosseous arteries arise in succession from the plantar arch as it crosses the fourth, third, and second intermetatarsal spaces, and pass forward, resting upon the interosseous muscles and covered by the tendons of the flexor longus digitorum and the lumbricales, and more distally by the transverse adductor of the great toe. Just before reaching the line of the metatarso-phalangeal articulations each artery gives off an *anterior perforating branch*, which passes dorsally to communicate with the corresponding dorsal interosseous artery, and then divides into two *plantar digital branches*, which pass onward upon the adjacent sides of neighboring digits.

The *fifth* plantar interosseous artery is considerably larger than the others, and arises from the inner end of the plantar arch, opposite the communicating branch which passes between the plantar arch and the dorsalis pedis. It runs forward at first along the first intermetatarsal space and then upon the first metatarsal bone, and gives off a digital branch which passes to the inner surface of the great toe and continues on towards the metatarso-phalangeal joint of that digit. Before reaching this, however, it gives off an anterior perforating branch and then divides into two plantar digital branches, which supply respectively the inner side of the second and the outer side of the great toe.

Since the communicating branch which traverses the first intermetatarsal space is sometimes regarded as the terminal portion of the dorsalis pedis artery, and the fifth plantar interosseous artery seems to be, upon such a view, the branch of the communicating vessel, the fifth plantar has been described as a branch of the dorsalis pedis artery, under the name of the *a. princeps hallucis*. There can be no doubt, however, that both the communicating and the princeps are equivalent to the other posterior perforating and plantar interosseous arteries.

Fig. 740.

Arteries of plantar surface of right foot; deeper dissection.

Variations.—The external plantar artery may be quite small, in which case the plantar arch seems to be a continuation from the anterior tibial artery through the posterior perforating branch of the first intermetatarsal space. The arch is occasionally double, owing to its division at its origin into two stems which reunite opposite the first intermetatarsal space. The first plantar interosseous may arise by a common stem with the second, and, conversely, one or more of the plantar digital branches may have an independent origin from the arch.

Anastomoses of the Posterior Tibial Artery.—A collateral circulation for the posterior tibial after interruption of that vessel below the origin of the peroneal may readily be established through the anastomoses which its branches form with those of the peroneal and those of the anterior tibial. The anastomoses with the peroneal are between the communicating branches of the two arteries, between the anterior peroneal and the external plantar, and between the posterior peroneal and the internal calcaneal. With the anterior tibial artery there is communication through the malleolar branches of the two arteries, through the anastomotic branch of the external plantar and the tarsal and metatarsal branches of the dorsalis pedis, and through the union of anterior and posterior perforating branches of the plantar arch and the plantar interosseous arteries with the dorsalis pedis and dorsal interosseæ.

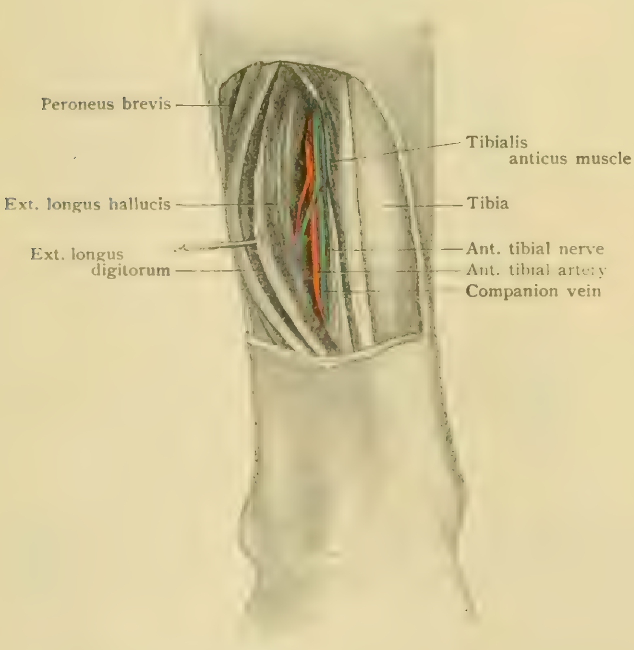
THE ANTERIOR TIBIAL ARTERY.

The anterior tibial artery (a. tibialis anterior) (Figs. 742, 743) is the other terminal branch of the popliteal. It begins at the lower border of the popliteus muscle, and is at first directed forward, passing between the tibia and fibula and the two uppermost slips of origin of the tibialis posticus, above the upper border of the interosseous membrane. It then bends downward and traverses the entire length of the crus to the front of the ankle-joint, where it becomes the dorsalis pedis artery. Its course may be represented by a line drawn from the head of the fibula to a point half-way between the two malleoli.

Relations.—In its course down the leg the anterior tibial artery rests *posteriorly* upon the interosseous membrane, to which it is more or less firmly united by fibrous bands; in the lower quarter of its course it rests upon the front of the tibia. *Anteriorly*, in the upper two-thirds of its course, it is overlapped by the tibialis anticus, lying along the deep edge of the connective-tissue partition which separates that muscle from the extensor longus digitorum and the extensor proprius hallucis. Lower, however, it is superficial, and just above the ankle-joint it is crossed obliquely, from without inward, by the tendon of the extensor proprius hallucis, and then passes beneath the anterior annular ligament. *Internally* to it is the tibialis anticus, and at the ankle-joint the tendon of the extensor proprius hallucis; *externally* it has in its upper third the extensor longus digitorum, in its middle third the extensor proprius hallucis, and at the ankle the inner tendon of the extensor longus digitorum. The anterior tibial nerve lies to the outer side of the artery in its upper and lower thirds; in the middle third of the leg it is usually in front of the vessel.

Variations.—The anterior tibial artery, as it occurs in man, appears to be the result of a union of two originally distinct vessels, both of which arise from the primitive peroneal artery and pass to the front of the leg. The uppermost of these forms the greater portion of the artery, while the lower one, which is represented by the anterior peroneal artery, forms only the lower part of the anterior tibial and its continuation upon the dorsum of the foot, the dorsalis pedis. In case of failure in the union of these two vessels, the anterior tibial may appear to terminate in muscular branches a short distance above the ankle-joint, the dorsalis pedis being the continuation of the anterior peroneal. This arrangement is not infrequent; more rarely the upper portion of the vessel is greatly reduced, being represented only by a small stem which gives off the posterior and anterior recurrent branches as well as branches to the popliteus muscle, the front of of the leg, in such cases, being sometimes supplied by an independent perforating branch from the posterior tibial.

FIG. 741.



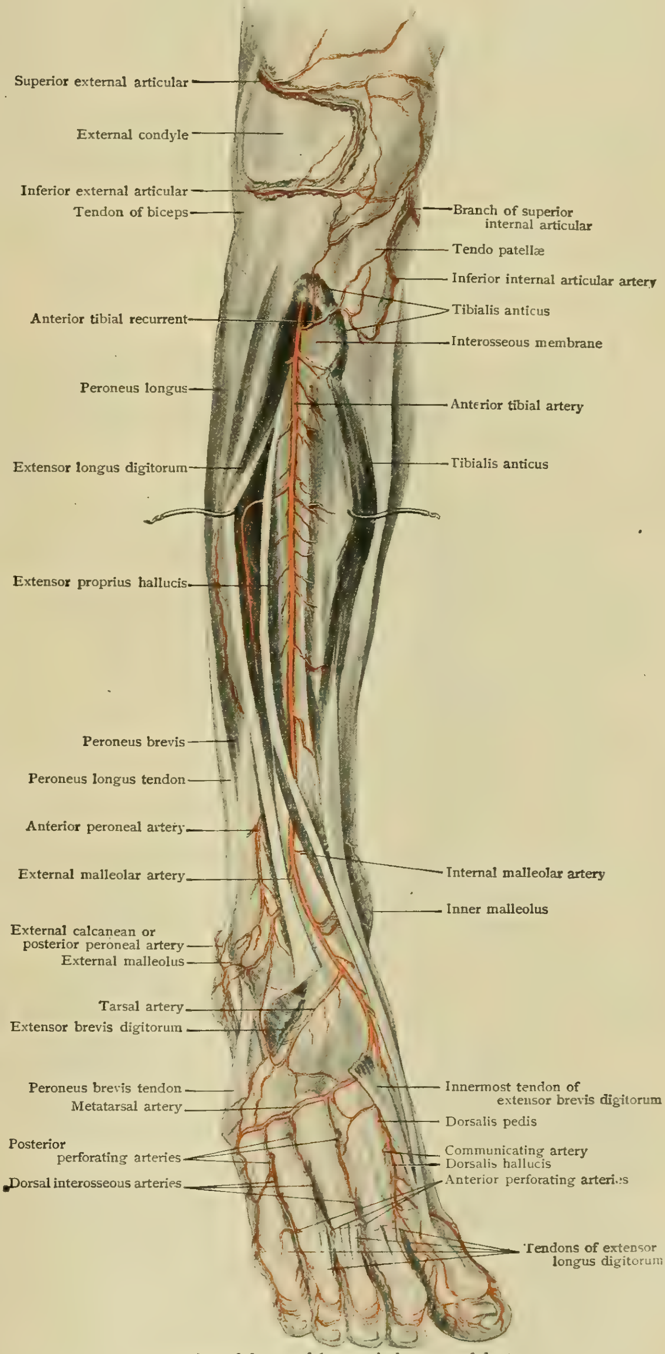
Dissection of middle third of right leg, showing relations of anterior tibial vessels and nerves; extensor muscles have been drawn aside.

Practical Considerations.—The anterior tibial artery is more often wounded than the posterior tibial because of its more exposed position on the front of the limb and its close relation to the tibia. It is not infrequently lacerated by the sharp edge of a fragment in fracture of that bone. It is

rarely the subject of aneurism. Ligation may be done at (1) the upper; (2) the middle; or (3) the lower third. The line of the artery is from a point midway between the external tibial tuberosity and the head of the fibula to the middle of the anterior intermalleolar space.

1. When through an incision made at this line the deep fascia is reached and divided, the interspace in which the artery lies should be sought for. It is that between the tibialis anticus and the extensor longus digitorum, is the only intermuscular interstice in the upper anterior tibial region, is about an inch or an inch and a quarter external to the tibial crest, and a half to three-quarters of an inch internal to the septum which divides the extensor longus from the peroneus longus. This septum is often marked by a white line visible before the deep fascia is divided; or it may be recognized by slipping a director outward beneath the aponeurosis until its point is firmly arrested. The interspace containing the anterior tibial artery will then be internal to this and can be felt as a line of lessened resistance when the forefinger is pressed lengthwise along the muscles (Treves). On the other hand, the aponeurotic partition between the extensor and the peroneus—external to the interspace sought for—resists and vibrates under the point of the director or the forefinger (Farabeuf). At the bottom of the interspace the artery will be found lying upon the interosseous membrane to the outer side of the tibia and with the nerve external to it.

FIG. 742.



Arteries of front of leg and dorsum of foot.

2. At the middle of the limb the same interspace is found—usually more easily, as there is often some yellowish-white fatty tissue lying between the muscles and seen as a line on the surface of the deep fascia—and is opened. The artery which still lies on the interosseous membrane will be found in the deeper space thus disclosed between the extensor proprius pollicis and the tibialis anticus.

3. At the lower third an incision on the same line will expose the vessel lying usually in the innermost of the two interstices found at that part of the limb, viz., that between the tibialis anticus and the extensor proprius pollicis. Occasionally it will be found to the outer side of the tendon of the extensor proprius—the second tendon from the tibia—in the space between that muscle and the extensor longus digitorum. The vessel lies on the front of the tibia, with the nerve external.

The *collateral circulation* is carried on from above the ligature by (*a*) the peroneals; and (*b*) the posterior tibial, anastomosing respectively with (*a*) the external malleolar, the branches of the dorsalis pedis and the plantar; and (*b*) the internal malleolar from below, assisted by the many small anastomotic vessels piercing the interosseous membrane and derived from the two tibials.

Branches.—In addition to numerous *muscular branches* which supply the adjacent muscles, the anterior tibial artery gives off the following:

1. The **superior fibular branch** (**ramus fibularis**) is a small vessel which arises from the anterior tibial immediately below its origin; occasionally it arises by a common trunk with the posterior tibial recurrent or else from the lower part of the popliteal. It passes upward behind the neck of the fibula, traversing the substance of the soleus, and sends branches to that muscle and to the peroneus longus, and anastomoses with the external inferior articular branch of the popliteal.

2. The **posterior recurrent tibial artery** (**a. recurrens tibialis posterior**) arises while the anterior tibial is still upon the posterior surface of the leg. It passes upward between the popliteal muscle and the posterior ligament of the knee-joint, both of which it supplies, and terminates by anastomosing with the external and internal inferior articular branches of the popliteal.

3. The **anterior recurrent tibial artery** (**a. recurrens tibialis anterior**) is given off just after the anterior tibial has reached the front of the leg. It runs upward in the substance of the tibialis anticus and over the outer tuberosity of the tibia, and terminates by taking part in the formation of the circumpatellar anastomosis. It gives branches to the tibialis anticus, the extensor longus digitorum, the capsule of the knee-joint, and the adjacent integument. This artery is of importance in the establishment of a collateral circulation after ligation of the popliteal artery (page 834), on account of its anastomoses with the descending branch of the external circumflex artery and with the anastomotica magna.

4. The **internal malleolar artery** (**a. malleolaris anterior medialis**) arises from the inner surface of the anterior tibial, a little above the ankle. It passes inward beneath the tibialis anticus, over the surface of the inner malleolus, and terminates by anastomosing with the malleolar branch of the posterior tibial, the internal plantar, and the internal calcaneal arteries.

5. The **external malleolar artery** (**a. malleolaris anterior lateralis**) arises from the outer surface of the anterior tibial, usually a little below the internal malleolar. It is directed outward and downward beneath the extensor longus digitorum and the peroneus tertius, over the surface of the external malleolus, and anastomoses with branches from the anterior and posterior peroneal arteries.

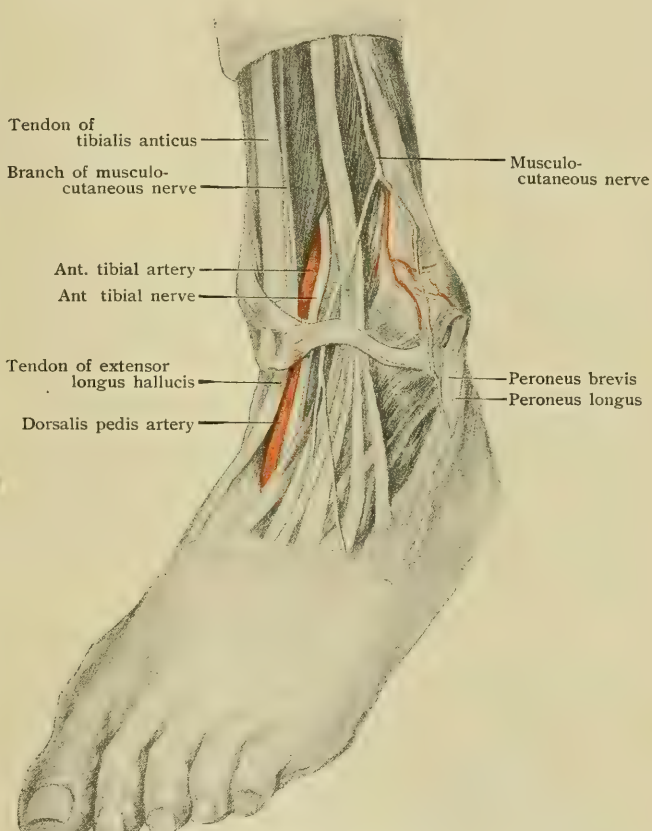
Anastomoses of the Anterior Tibial Artery.—Collateral circulation is readily established, in cases of interruption of the anterior tibial artery, by means of its abundant anastomoses with branches of the posterior tibial. Thus there are rich anastomoses between the internal malleolar branch of the anterior tibial and the malleolar branch of the posterior tibial, and between the external malleolar branch of the anterior tibial and the anterior and posterior peroneal branches. Further, since the dorsalis pedis artery is the continuation of the anterior tibial, it will assist materially in the collateral circulation by the anastomoses of its tarsal and metatarsal branches with the plantar and peroneal arteries and by its connections with the plantar arch.

THE DORSAL ARTERY OF THE FOOT.

The dorsal artery of the foot (**a. dorsalis pedis**) (Fig. 743) is the continuation of the anterior tibial beyond the ankle-joint. It extends to the proximal portion of the first intermetatarsal space, where it receives the large fourth perforating branch of the plantar arch, and is thence continued forward along the intermetatarsal space as the a. dorsalis hallucis.

Relations.—The dorsalis pedis is covered in the proximal portion of its course by the anterior annular ligament, and is crossed just before it reaches the intermetatarsal space by the tendon of the extensor brevis digitorum which passes to the great toe. It rests successively upon the anterior ligament of the ankle-joint, the head of the astragalus, the astragalo-scaphoid ligament, the dorsal surface of the scaphoid bone, the dorsal scapho-cuneiform ligament, and the intercuneiform ligaments which extend between the middle and internal cuneiform bones. *Externally* it is separated from the innermost tendon of the extensor longus digitorum and from the extensor brevis digitorum by the inner terminal branch of the anterior tibial nerve, and *internally* it is in relation with the tendon of the extensor hallucis proprius.

FIG. 743.



Dissection showing relations of vessels and nerves in vicinity of left ankle; portion of anterior annular ligament still in place.

Branches. — In addition to numerous *cutaneous branches* to the skin of the dorsum of the foot and *muscular branches* to the extensor brevis digitorum, the dorsalis pedis gives rise to the following vessels.

1. The **internal tarsal branches** (**aa. tarseae mediales**) are one or more small vessels which pass over the outer border of the foot, supplying the integument and the tarsal articulations and anastomosing with the internal malleolar and internal plantar arteries.

2. The **external tarsal branch** (a. tarsea lateralis) arises opposite the head of the astragalus and passes outward and forward over the scaphoid and cuboid bones, under cover of the extensor brevis digitorum. It gives branches to that muscle, to the skin, and to the tarsal articulations, and anastomoses with the external malleolus and anterior peroneal arteries above, with the external plantar laterally, and with the metatarsal below.

3. The **metatarsal branch** (a. arcuata) arises over the internal cuneiform bone and is directed at first laterally forward and then laterally over the bases of the four outer metatarsal bones and beneath the tendons of the extensor longus and extensor

brevis digitorum. It thus forms an arch upon the dorsal surface of the foot corresponding in position with the plantar arch below. It anastomoses laterally with the external tarsal and with the external plantar, and opposite each of the intermetatarsal spaces which it passes—the second, third and fourth—gives off a **dorsal interosseous artery** (**a. metatarsea dorsalis**).

Each of these passes forward along its intermetatarsal space, and, immediately beyond its origin, gives off a *posterior perforating branch* which communicates directly with the corresponding posterior perforating branch of the plantar arch. At the distal end of its intermetatarsal space each artery gives off an *anterior perforating branch* which unites with the similar branch of the corresponding plantar interosseous, and then divides into *two dorsal digital branches* (**aa. digitales dorsales**) which pass along the adjacent surfaces of two neighboring digits and anastomose with one another and with the plantar digital branches.

4. The **dorsal interosseous branch of the first intermetatarsal space** appears to be the continuation of the dorsalis pedis, and is usually termed the **a. dorsalis hallucis.** Its course is exactly similar to that of each of the other dorsal interosseous arteries, except that, in addition to the anterior dorsal perforating and terminal dorsal digital branches, it gives off, not far from its origin, a *third digital branch* which passes forward along the outer surface of the great toe. The posterior communicating artery which should arise from this vessel is represented by the large branch by which the dorsalis pedis communicates with the plantar arch.

Variations.—The origin of the dorsalis pedis from the peroneal by means of the anterior peroneal branch has already been noted in connection with the variations of the anterior tibial artery. Another origin which has been observed is from the external plantar artery, which sends upward through the astragalo-calcaneal canal a large branch which is continued distally upon the dorsum of the foot and gives off the tarsal and metatarsal branches. This vessel is represented in the adult by a small branch which arises from the external tarsal artery and pursues the course indicated to anastomose with the external plantar; it appears to be much more highly developed in the embryo than in the adult (Leboucq).

Other variations in the dorsalis pedis and its branches depend upon a correlation which exists between the development of the dorsal and plantar system of vessels. If, for example, the plantar interosseæ are well developed, they will, through the anterior perforating branches, furnish the main blood-supply for the dorsal digital branches, and the dorsal interosseous vessels, as well as the metatarsal, may be much reduced. Or the plantar arch, through the posterior perforating branches, may be the main supply for the dorsal interosseous vessels, and the dorsalis pedis itself may be diminished in size or may even terminate in a net-work of small vessels over the dorsal surface of the tarsus.

DEVELOPMENT OF THE ARTERIES.

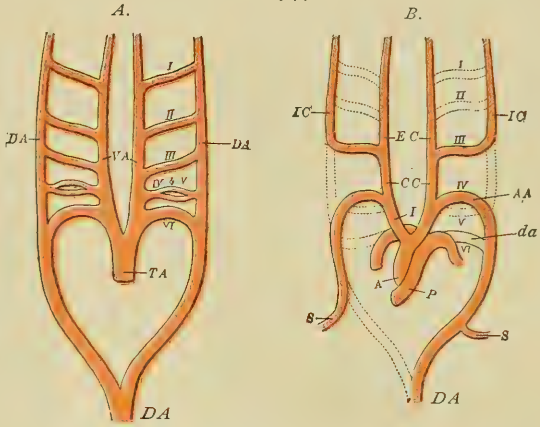
In the preceding pages some of the more important facts regarding the development of the arteries have been mentioned in connection with the anomalies in whose production they are concerned; these facts may now be briefly restated in a more connected manner.

At an early stage of development, while the heart lies far forward beneath the pharyngeal region and its ventricle is still undivided, the blood leaves it by a single vessel which passes forward along the mid-ventral line of the pharynx and divides to form two ventral longitudinal stems, from each of which six lateral branchial vessels arise, the fifth vessel of each stem, counting from before backward, being quite rudimentary and closely associated with the fourth. These branchial vessels pass dorsally in the branchial arches to the dorsal surface of the pharynx, where those of each side unite to form a longitudinal stem which passes backward, and at about the level of the eighth cervical vertebra unites with its fellow of the opposite side to form a single longitudinal trunk, the *dorsal aorta* (Fig. 677). This is continued backward to the posterior extremity of the trunk, lying immediately ventral to the vertebral column. From the anterior ends of the ventral and dorsal longitudinal stems branches pass forward into the cranial region; and from the dorsal longitudinal stems and the dorsal aorta lateral and ventral branches are given off in regular segmental succession. The modifications undergone by the branchial arch vessels in the course of development may first be traced and then the arrangement and modifications of the segmental branches will be considered.

The first modification of the branchial arch vessels consists in the disappearance of the two anterior ones on either side, and then follow a number of changes which may be briefly stated as follows. (1) The portions of the dorsal longitudinal stems intervening between the third and fourth branchial vessels disappear; (2) the fifth branchial vessels disappear; (3) the sixth loses its connection with the dorsal longitudinal stem on the right side; (4) the proximal portion of

the ventral longitudinal stem divides in the frontal plane into two portions, one of which is connected with the sixth branchial vessels, while the other retains the remaining ones ; and (5) the posterior portion of the right dorsal longitudinal stem disappears, so that the dorsal aorta is formed only by the left stem (Fig. 678). As the result of these changes the anterior portion of the ventral longitudinal stem becomes the external carotid artery ; the anterior portion of the dorsal longitudinal stem the internal carotid ; the third branchial vessel becomes the connection between the two carotids ; the fourth branchial vessel of the left side, together with the left dorsal longitudinal stem, becomes the arch of the aorta ; the right fourth branchial vessel and the persisting portion of the right dorsal longitudinal stem become the proximal portion of the right subclavian artery ; the sixth branchial vessels become the pulmonary arteries, the persisting connection of the left one with the aortic arch being the ductus arteriosus ; the proximal portion of the ventral longitudinal trunk which remains connected with the sixth vessels becomes the pulmonary aorta, while the other portion becomes the proximal part of the aortic arch. These changes are shown diagrammatically in Fig. 744, *A* and *B*.

FIG. 744.



Diagrams illustrating primary arrangement (*A*) and secondary modifications (*B*) in branchial arch vessels. *TA*, truncus arteriosus; *I-VI*, aortic bows; *VA*, *DA*, ventral and dorsal aortæ; *A*, aorta; *AA*, aortic arch; *I*, innominate artery; *CC*, *CE*, *CI*, common, external and internal carotids; *S*, subclavian; *P*, pulmonary artery; *da*, ductus arteriosus.

From the forward prolongations of the carotid arteries the vessels which supply the cranial structures are developed, and lateral branches also pass from the carotids to the structures which are formed from the branchial arches. Of these branches the superior thyroid, lingual, and facial arteries are probably from the beginning connected with the external carotid, but the greater part of the internal maxillary takes its origin from the internal carotid and only secondarily becomes connected with the external one (page 743).

From the dorsal longitudinal stems, posterior to the point at which the sixth branchial vessels join them, branches pass off laterally to each of the cervical segments, the most anterior pair accompanying the hypoglossal nerve and passing to the occipital segments with which the nerve is associated. Later, as the heart recedes towards its final position in the thorax, carrying with it the dorsal longitudinal stems, the majority of the cervical lateral branches separate from the stems and are represented in the adult by the segmental muscular and spinal branches which arise from the vertebral artery. The seventh branches, however, retain their connection with the longitudinal stems and become the subclavian arteries of the adult.

FIG. 745.

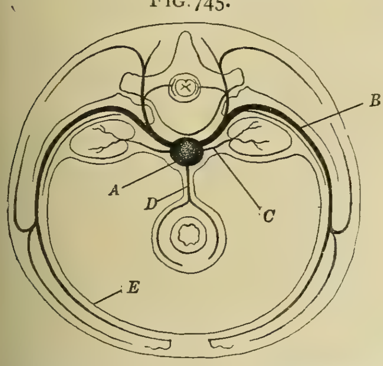


Diagram showing fundamental arrangement of branches from aorta (*A*); *B*, lateral branches to body-wall; *C*, paired visceral, *D*, unpaired visceral branch; *E*, peritoneum.

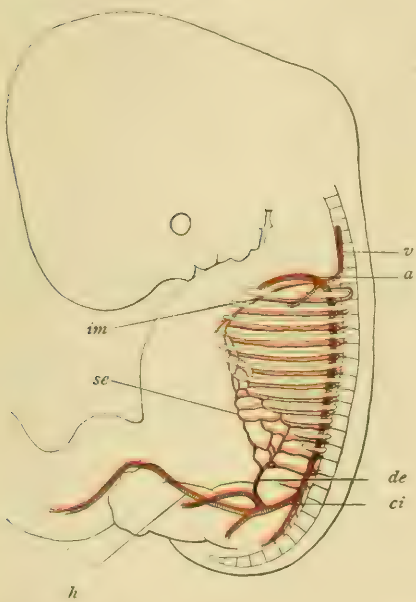
Throughout the entire length of the dorsal aorta segmental branches are distributed not only to the body-wall, but also to the viscera, and in each segment two typical sets of visceral branches may be distinguished,—a pair of lateral branches which pass laterally beneath the peritoneum to the paired viscera, and a single median branch which passes ventrally in the mesentery and is supplied to the digestive tract and its derivatives (Fig. 745). The lateral branches to the body-wall persist in the adult as the intercostal lumbar and lateral sacral branches, the fifth lumbar branches entering into the formation of the iliac arteries. The visceral branches belonging to both sets, however, undergo much modification, some disappearing and others fusing, so that little trace of their primary segmental arrangement is to be recognized in the adult. Representatives of the paired visceral branches are to be found in the bronchial, suprarenal, renal, and spermatic (ovarian) arteries, and in the fœtus the umbilical arteries represent the paired branches of the third lumbar segment. At an early stage, however, these vessels make connections with branches of the iliac arteries and

then lose their original connections with the aorta, so that they seem in the fœtus to arise from the iliac vessels, and these latter, although primarily somatic in their distribution, give off a number of visceral branches.

Of the unpaired visceral branches representatives are to be found in the thoracic region in the œsophageal and mediastinal vessels and in the abdomen in the cœliac axis and the superior and inferior mesenteric arteries, the superior mesenteric representing the omphalo-mesenteric or vitelline arteries of the embryo which primarily arise by several roots, only the lowest of which persists to form the adult vessel.

According to the general plan of the embryonic arterial system thus outlined, the only vessels which have primarily a longitudinal course are the dorsal and ventral longitudinal stems, the dorsal aorta, and its prolongation, the a. sacra media. In the adult, however, several other longitudinal vessels exist, such, for instance, as the vertebrals, the internal mammaries, and the superficial and deep epigastrics. All these vessels are secondary formations due to the end-to-end anastomoses of upwardly and downwardly directed branches of the lateral segmental vessels. The internal mammaries and the epigastrics (Fig. 746) are formed in this manner from branches of the intercostal arteries, with which they remain connected to a greater or less extent; the vertebrals are formed from branches of the lateral cervical vessels, and become independent stems by the separation of these vessels from the dorsal longitudinal stems, as already described.

FIG. 746



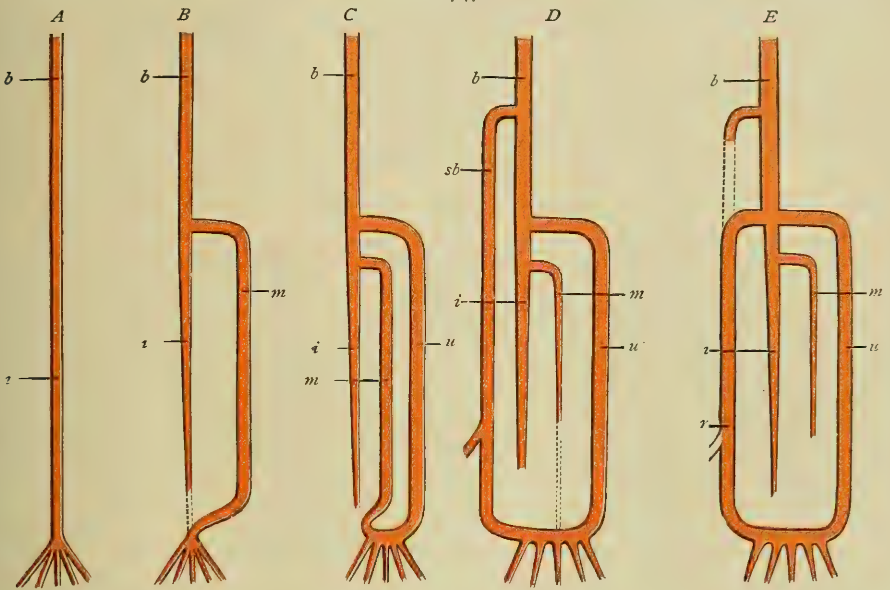
Trunk-arteries of embryo of six weeks, showing origin of internal mammary (*im*) and epigastric arteries (*se*, superficial, *de*, deep); *a*, aorta; *v*, vertebral; *ci*, common iliac, continuing as large hypogastric (*h*); external iliac, giving off deep epigastric and femoral, is still small. × 5. (*Mall.*)

The arteries of the limbs are formed, as already stated, by the lateral somatic branches of the seventh cervical and fifth lumbar segments respectively, but in both limbs a series of changes is necessary before the adult arrangement is acquired. In the arm the subclavian artery at first extends as a single main stem as far as the carpus, where it terminates by dividing into digital branches for the fingers (Fig. 747, *A*). Throughout its course in the forearm it lies between the two bones, resting on the interosseous membrane, in the position occupied by the adult anterior interosseous artery; from the upper part of this portion of its course a branch is given off which takes a more superficial course, accompanying the median nerve. This median artery gradually becomes larger, while the anterior interosseous undergoes a corresponding retrogression, and eventually the median, by fusing with the lower portion of the interosseous, forms the main channel for the digital branches and becomes the principal artery of the forearm (Fig. 747, *B*). A further stage is marked by the development of the ulnar artery as a branch from the brachial, and this, extending down the ulnar side of the forearm, unites with the median to form a carpal arch from which the digital branches arise (*C*). Later there develops high up upon the brachial a superficial brachial artery, which, after traversing the brachium, passes down the radial side of the forearm and near the wrist passes to the posterior surface, dividing over the carpus into branches for the dorsum of the thumb and index-finger. After the appearance of the ulnar artery a retrogression of the median begins, whereby it becomes the a. comes nervi mediani of the adult; a branch, the superficial volar, arises from the lower part of the superficial brachial and passes downward into the palm to unite with the palmar arch already present (*D*); and, finally, a branch arising from the lower part of the brachial anastomoses with the superficial brachial just below the bend of the elbow and together with the antibrachial part of the superficial brachial, forms the radial artery. The upper part of the superficial brachial then degenerates until it is normally represented in the adult by a small branch of the brachial which passes to the biceps muscle (*E*).

In the leg the changes are equally complicated. Primarily it is the sciatic artery which forms the main stem, extending the entire length of the posterior surface of the limb into the plantar surface of the foot, where it divides into the digital branches (Fig. 748, *A*). The external iliac at this stage is a relatively slender vessel which extends but a short distance down the thigh and terminates in what is later the profunda femoris. In a later stage there arises from

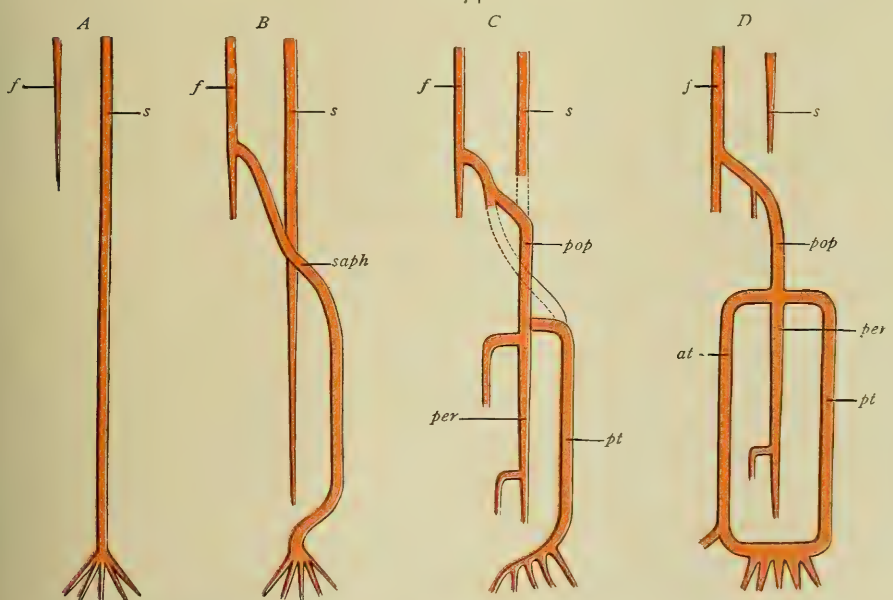
the external iliac a vessel (*saph*) which accompanies the internal saphenous nerve down the leg and, entering the foot, takes from the original main stem its digital branches (*B*). From this saphenous artery a branch is given off which pierces the substance of the adductor magnus mus-

FIG. 747.



Diagrams illustrating development of arteries of upper limb; *b*, brachial; *i*, interosseous; *d*, digital; *m*, median; *u*, ulnar; *sb*, superficial brachial; *r*, radial.

FIG. 748.



Diagrams illustrating development of arteries of lower limb; *s*, sciatic; *d*, digital; *f*, femoral; *saph*, saphenous; *pop*, popliteal; *per*, peroneal; *pt*, *at*, posterior and anterior tibial.

cle and anastomoses with the sciatic artery just above the upper end of the popliteal space (*C*), whereupon the portion of the sciatic artery immediately above the anastomosis degenerates and

the vessel becomes reduced to the slender a. comes nervi ischiadici of the adult. Its lower portions, which become the popliteal and peroneal arteries, now seem to be the continuation of the femoral (*i.e.*, the saphenous).

From the lower part of the popliteal a branch arises which anastomoses with the saphenous and, together with the lower part of that artery, forms the posterior tibial, the upper part of the saphenous then disappearing except in so far as it is represented by one of the branches of the anastomotica magna. The anterior tibial is a late formation resulting from the fusion of an upper and lower branch from the peroneal which perforate the interosseous membrane (*C*), the connection of the lower branch with the peroneal degenerating after the anastomosis, except in so far as it persists as the anterior peroneal artery (*D*).

THE VEINS.

The veins are those vessels which receive the blood from the capillary net-work and return it to the heart.

Compared with the arteries, they present many differences, both of structure (page 677) and arrangement. Their walls are much thinner, so that the color of the blood which they contain shows through, and they are readily compressible to the extent of a complete obliteration of their lumen and are also exceedingly dilatable. Notwithstanding their thinness, they are less easily ruptured by over-distention than are the arteries and are capable of undergoing a remarkable elongation, those of an adult withstanding an extension to at least 50 per cent. more than their original length without losing their elasticity—a property which explains the more direct course taken by the veins as compared with the arteries in mobile portions of the body (*e.g.*, the facial vein as compared with the artery). Indeed, it seems that the veins when in place in the body are always stretched to a considerable extent, the cephalic vein, for example, contracting when removed from the body to 40 per cent. of its length in the extended arm (Bardeleben).

The most striking structural peculiarity of the veins, however, is the occurrence in them of semilunar **valves,** arranged usually in pairs, with their cavities directed towards the heart. These valves resemble in their general form the semilunar valves of the systemic and pulmonary aortæ, and, as in those vessels, the veins are somewhat enlarged immediately above the attachment of each pair, so that the blood may readily flow behind the valves, force their free margins together and so occlude the vessel. These valves play an important part in directing the flow of blood in the veins towards the heart, since, in the event of any pressure, such as that exerted by a contracting muscle, acting on the vein, they will prevent a backward flow of blood towards the capillaries. Valves do not occur in veins of less than 1 mm. in diameter and are also lacking in many of the larger trunks, such as the superior and inferior venæ cavæ, the pulmonary and the portal veins. In general they are more numerous in the veins of the limbs than in those of the trunk and in the deep than in the superficial vessels.

Their number in any vessel in which they normally occur is subject to considerable variation in different individuals and even on opposite sides of the body in the same subject. It seems probable that this variation is brought about by a degeneration of a greater or less number of the pairs originally present, since in the majority of the veins the number of valves diminishes with age (Bardeleben), and even in adult bodies evidence of degeneration may be seen in the insufficiency of some of the valves or even in their perforation. It is possible, therefore, that the arrangement of the valves in the adult is a secondary condition, derived from one in which the valves were much more numerous and were situated at regular intervals along the vessels. In favor of this view it has been found (Bardeleben) that in certain veins the valves in the adult are separated by intervals either of a definite length or of a multiple of this, the length of the intervals standing in relation to the length of the part or, in general, to the height of the individual in which the vein occurs. Thus, in a man measuring 160 mm. in height, the valves of the right long saphenous vein were separated by intervals which were all approximately multiples of 6.85 mm. in length, while the intervals separating the valves of the right cephalic vein were approximately multiples of 5.2 mm.; and in a male child 81 cm. in height, the valves of the right long saphenous vein were separated by intervals of 3 mm. or some multiple of this.

A more readily appreciable relation of the valves is that which they bear to the branches which open into the vein, a pair of valves being found immediately distal to the entrance of each collateral vein ; and, furthermore, a pair, or at least a single valve, very generally occurs at the termination of a vein, where it enters either a larger stem or the heart. These terminal valves are present in certain veins which otherwise are quite destitute of valves, as, for instance, in the internal jugular, the internal maxillary, and the vertebral veins.

It has already been noted that valves are entirely wanting in certain veins. Among these are the sinuses of the cranium, the cerebral, ophthalmic, periosteal, pulmonary, bronchial, portal, renal, uterine, ovarian, and innominate (brachio-cephalic) veins, and the superior and inferior venæ cavæ. Furthermore, they are usually absent in the internal iliac and facial veins, although occasionally they occur in both.

In their position and arrangement also the veins differ noticeably from the arteries. While veins are usually to be found accompanying the arteries, enclosed with them in a common fibrous sheath, additional veins of considerable size are abundant immediately beneath the skin—a condition which is almost entirely foreign to the arteries. Furthermore, although in a general way a vein may pursue the same course as an artery, it may lie at some little distance from the latter and fail to follow its course exactly. This is true, for instance, of the facial and the lingual veins and also of the subclavian vein, which is separated from the corresponding artery by the scalenus anticus muscle ; this likewise applies to the veins at the root of the neck which accompany in a general way the branches of the subclavian artery, but open into the innominate vein instead of the subclavian. In many cases the veins which accompany arteries are double, one lying on either side of the artery and forming what are generically known as **venæ comites** (venae comitantes). The causes which determine this double condition are obscure. The arrangement is not found in the larger venous trunks, occurring, for instance, in the leg only below the knee and in the arm only as far up as the middle of the brachium ; size alone, however, does not seem to be the determining factor, since the internal mammary and epigastric veins are double, while the intercostal and lumbar veins, almost of the same size as the former, are single. Nor does the quality of the tissue in which the veins occur determine their duplication, for those which are embedded within the muscles of the tongue are doubled, while those within the heart musculature are single ; again, while, as a rule, the veins which occur in fibrous tissue—as, for instance, the meningeal veins—are double, yet those of the skin are single. Finally, it may be noted that there are exceptions to the rule that the veins which occur in the cavities of the body are single, since a duplication is found in the spermatic veins and also in those of the gall-bladder.

Not only doubling of many of the veins occurs, but a prevailing tendency exists towards extensive anastomoses far surpassing that displayed by any of the arteries. Even in the cases of the larger proximal trunks communications exist, those between the pulmonary and bronchial veins and that between the superior and inferior venæ cavæ by way of the azygos being examples. In the smaller vessels the anastomoses are often so numerous as to result in the formation of plexuses. Venæ comites are united by frequent cross-connections, sometimes so numerous as to present the appearance of a plexus surrounding the artery. Complicated venous plexuses also accompany the various ducts of the body, as, for example, the parotid ducts, the ureters, and the vasa deferentia. In addition, extensive venous plexuses occur in various regions of the body, as in the neighborhood of its orifices, in the terminal phalanges of the fingers and toes, in the diploë of the skull, in the spinal canal, in the pelvis, and in connection with the genito-urinary organs. Since the larger trunks usually arise at several points both from these and from the wider-meshed plexuses occurring elsewhere, opportunity is thus afforded for the return of the blood to the heart by different paths—an arrangement explaining the frequent inefficiency of a ligation of even large trunks to prevent venous hemorrhage.

Special mention should be made of one set of the venous channels—namely, the *sinuses of the dura mater*—which establish communication between the cerebral and ophthalmic veins and the internal jugular. They are channels contained within

the dura mater, lined by an endothelium similar to and continuous with that of the extracranial veins, but lack any extensive development of elastic fibres in their walls, which are formed by the dura. They possess no valves, although in certain of them, as in the superior longitudinal and cavernous sinuses, the lumen is traversed by irregular trabeculæ of fibrous tissue. These are especially well developed and almost tendinous in character in the superior longitudinal sinus, while in the cavernous sinus they are softer, and from them and from the walls of the sinus fringe-like prolongations, .5-2 mm. in length, project freely into the lumen. Connected with certain of these sinuses and developed from certain of the smaller veins which open into them are so-called **blood-lakes** (**lacunae**)—cavities or plexuses in the dura mater, lined with endothelium, and connecting either directly or by means of a short canal with an adjacent sinus. They are usually situated more or less symmetrically with reference to the sinus with which they are connected, and some are very constant in occurrence. Thus, a certain number usually occur on either side of the superior longitudinal sinus (page 1199), others in the tentorium cerebelli connecting with the lateral sinus, others in the middle fossa of the skull along the course of the meningeal veins, and others in the vicinity of the straight sinus. They occasionally reach a considerable size, bulging outward the dura which encloses them and excavating by absorption irregular depressions upon the inner surface of the skull. Occasionally this absorption of the cranial bones proceeds so far that bulging of the outer table of the skull over a lake takes place, and, in the case of those occurring along the course of the superior longitudinal sinus, Pacchionian bodies developed from the subjacent arachnoid tissue may invade them, pushing before them the attenuated floors of the lakes.

Classification of the Veins.—Theoretically a description of the veins should start with the peripheral vessels and proceed towards the great trunks, following the course of the blood. Such a method would prove, however, somewhat confusing, largely on account of the numerous anastomoses that occur ; it is preferable, therefore, to base a classification primarily upon the great trunks and to consider their afferents topographically, according to the areas which they drain.

From the embryological stand-point, there are primarily four great systems of veins : (1) the *cardinal system*, represented by the vena cava superior and its tributaries ; (2) the *inferior caval system ;* (3) the *portal system ;* and (4) the *pulmonary system*. Owing to subsequent changes, it is necessary to recognize in the cardinal system three sub-systems : (1) that of the cardiac veins ; (2) that of the superior vena cava and its tributaries, except (3) the azygos veins. In all, then, six great systems of veins may be recognized in the adult. They are as follows :

1. The pulmonary system.
2. The cardiac system. ⎫
3. The superior caval system. ⎬ The cardinal system.
4. The azygos system. ⎭
5. The inferior caval system.
6. The portal system.

In the descriptions which follow the veins are considered on the basis of this classification.

THE PULMONARY SYSTEM.

The Pulmonary Veins.

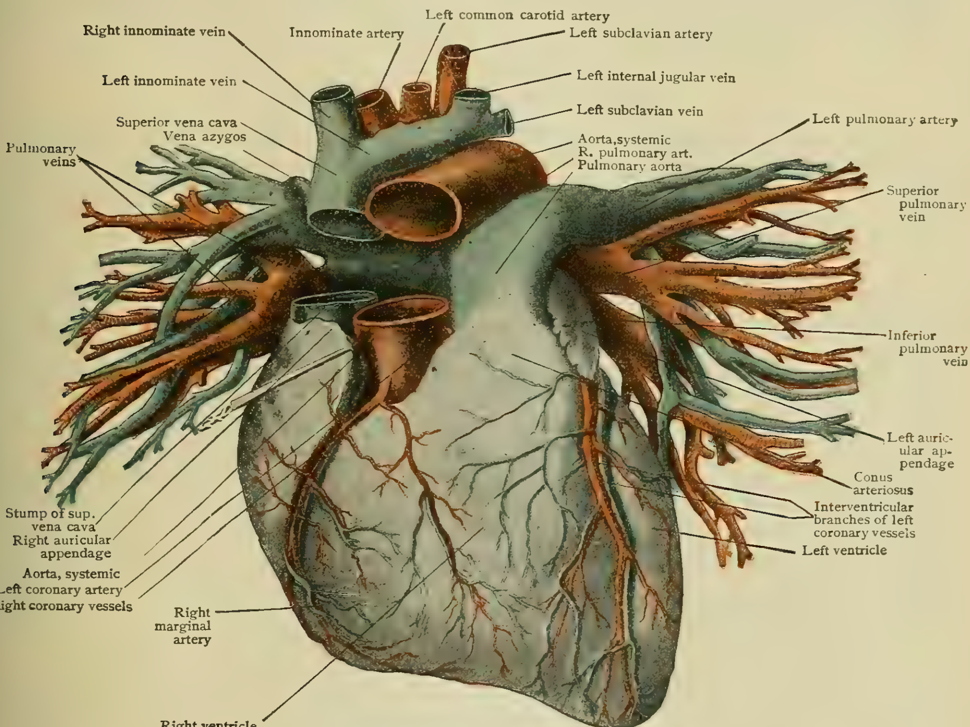
The pulmonary veins (**venae pulmonales**) (Figs. 749, 750) are four in number, two passing from the hilum of each lung to the posterior surface of the left auricle of the heart. Each vein is formed at the hilum of its lung by the union of a number of smaller vessels which take origin ultimately from the capillary net-work formed by the branches of the pulmonary artery and to a certain extent from that formed by the bronchial arteries. The arrangement of the afferent branches in the substance of the lungs is described in connection with the anatomy of these organs (page 1854), and it will be sufficient to note here that they correspond in number to the branches of the pulmonary artery and of the bronchi, and pursue a course more or less independent of these, which lie side by side. Converging and uniting as they pass towards the hilum, the branches from the superior lobe of each lung unite to form the **superior**

pulmonary vein of that side, those from the inferior lobe unite to form the **inferior pulmonary vein,** while those from the middle lobe of the right lung unite to form a single trunk which usually opens into the right superior vein, although it occasionally opens independently into the left auricle, forming what is then termed the *middle pulmonary vein.*

Each of the four pulmonary veins has a length of about 15 mm., and for about one-third of its course is partially invested by the visceral layer of the pericardium (page 715). The right superior vein is usually slightly the largest of the four, while the left superior is the smallest, the right and left inferior veins being about the same size. No valves occur either throughout the course or at the orifices of the pulmonary veins.

Relations.—The superior pulmonary veins have a course which is obliquely downward and inward. In their extrapericardial portion they lie anterior to and below the pulmonary arteries, and are separated by them from the bronchi; the

FIG. 749.



Injected heart and great vessels, viewed from before; parts of superior vena cava and aorta have been removed to show right pulmonary artery.

vein of the right side is crossed from above downward by the phrenic nerve and by the vena cava superior. In its intrapericardial portion the right superior vein lies behind the terminal portion of the superior vena cava and the left one behind the pulmonary aorta (pulmonary artery), while posteriorly each is in relation with its corresponding inferior vein.

The inferior veins are more horizontal in position, but are directed forward as well as inward. They lie in a plane considerably posterior to that of the corresponding superior veins and are situated internally to and behind an anterior descending branch of each bronchus.

Anastomoses.—In addition to serving for the return flow of the blood carried to the lungs by the pulmonary arteries, the pulmonary veins also receive a certain amount of the blood carried by the bronchial arteries. Communications between

the bronchial and pulmonary veins in the region of the smaller bronchi are abundant, and, in addition, the main stems of the pulmonary veins receive at the hilum of the lung one or more branches from the larger bronchial veins. They also receive communications from the venous plexus which surrounds the thoracic aorta in the posterior mediastinum, and occasionally also a vein from the pericardium. There is thus a certain commingling of venous blood with the arterialized blood which forms the principal contents of the pulmonary veins.

Variations.—At one stage in the development of the embryo the veins from each lung converge to a single short trunk before opening into the portion of the atrium which corresponds to the left auricle. As the development of the heart proceeds, this trunk is gradually taken up into the auricle, until the two stems which unite to form it open independently into that structure. An inhibition of this process occasionally obtains, so that but a single vein, representing the original terminal trunk, opens into the auricle from one lung or from both. On the other hand, the taking up of the pulmonary vein into the wall of the auricle may proceed further than usual, or, to state it perhaps more correctly, the union of the various stems emerging from the hilum of the lung may be partly delayed until they have reached the original terminal trunk, so that when this is taken up into the auricle an additional vein will open independently into the latter. This extra vein is most frequently that from the middle lobe of the right lung, but three distinct veins have also been observed upon the left side.

THE CARDINAL SYSTEM.

The cardinal system of veins is so named because its main trunks are the representatives of the *cardinal veins* of the embryo. These veins are four in number, disposed symmetrically in pairs, two returning the blood from the head, neck, and upper extremities, while the other two return that from the thoracic and abdominal walls, from the thoracic viscera, and from the lower extremities. Just before they reach the heart, the *superior* and *inferior* or *posterior cardinal veins* of each side unite (Fig. 776) to form trunks known as the *ducts of Cuvier*, the two ducts opening independently into the primitive right auricle. By a series of changes, which are described more fully in the section on the development of the veins (page 927), the left superior cardinal becomes connected with the right at the base of the neck, the stem so formed constituting what is termed the superior vena cava. The portion of the left superior cardinal between the connecting vessel and the heart becomes greatly reduced in size, indeed, almost completely degenerates; the left duct of Cuvier, however, persisting as the coronary sinus, which receives the coronary veins returning the blood from the heart's walls. On the development of the vena cava inferior the veins of the lower extremity make connection with it, separating from the inferior cardinals; these latter become considerably reduced in size, especially in the abdominal region, a cross-connection develops between the left and right veins, and the former severs its connection with the left ductus Cuvieri, the final result being the formation of the venæ azygos and hemi-azygos of the adult.

There are, then, developed from the cardinal veins of the embryo three subsystems of veins: (1) that of the cardiac veins; (2) that of the superior vena cava, which includes the jugular and subclavian groups of veins, the original superior cardinals being represented by the internal jugular veins; and (3) the azygos subsystem. These will be considered in the order in which they have been named.

THE CARDIAC VEINS.

THE CORONARY SINUS.

The coronary sinus (**sinus coronarius**) (Fig. 750) is a short venous trunk about 3 cm. (a little over an inch) in length, which occupies the right half of that portion of the posterior auriculo-ventricular groove which lies between the left auricle and ventricle. At its right end it opens into the right auricle, its orifice (Fig. 657) being situated upon the posterior surface of the auricle, below that of the inferior vena cava, and being guarded by the *Thebesian valve* (**valvula sinus coronarii**). At its left end it receives the great coronary vein, from whose proximal portion it is not always clearly distinguishable upon superficial examination. A close inspection usually reveals, however, either a constriction or a slight dilatation at the union of the two vessels, and on

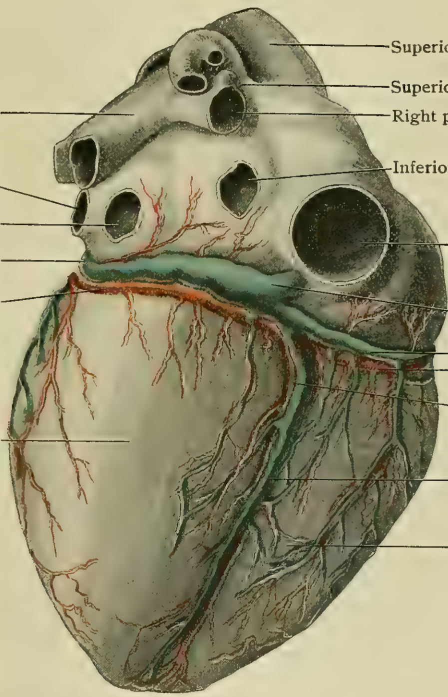
laying them open a distinct valve, of either one or two cusps, but usually insufficient, will be found at their line of junction. This valve is known as the *valve of Vieussens.* Furthermore, the walls of the sinus differ from those of the vein in possessing a complete layer of muscular fibres, both oblique and circular, continuous with the musculature of the auricle.

In addition to the great coronary vein, the coronary sinus also receives the posterior vein of the left ventricle and the middle cardiac vein, which open into it from below, and the oblique vein of the left auricle, which passes to it from above.

Variations.—The coronary sinus, as already stated, represents the left ductus Cuvieri of the embryo. It varies somewhat in length, reaching in extreme cases a length of 5.4 cm. It has been observed to be obliterated at its entrance into the right auricle, the great coronary vein then opening into the left innominate (brachio-cephalic) vein, and, in addition to the veins already noted as emptying into it, it frequently receives the marginal vein of the left ventricle.

1. **The Left Coronary Vein.**—The great cardiac or left coronary vein (**v. cordis magna**) (Fig. 749) begins upon the anterior surface of the heart at the apex, where it anastomoses with the veins of the posterior surface, and ascends the anterior

FIG. 750.



Posterior-inferior aspect of injected heart, showing blood-vessels.

interventricular groove in company with the left coronary artery, to the anterior auriculo-ventricular groove, in which it passes to the left and, curving around the left border of the heart to the posterior surface, terminates by opening into the left end of the coronary sinus.

In the vertical portion of its course it receives veins from the anterior surface of both ventricles, and in its course in the auriculo-ventricular groove, throughout which it is embedded in the fat which usually occupies the groove, it receives a number of small veins from the surfaces of both the left auricle and ventricle. Among those from the ventricle there is especially to be mentioned, as larger and more constant than the rest, the **vena marginalis sinistra**, which ascends along the left border of the heart and empties into the great coronary vein shortly before its opening into the sinus.

2. **The Posterior Cardiac Vein.**—The posterior cardiac vein (**v. posterior ventriculi sinistri**) ascends along the posterior surface of the left ventricle, lying about midway between the left border of the heart and the posterior interventricular groove and receiving collateral branches from the walls of the ventricle. It opens above into the coronary sinus near the point of entrance of the great coronary vein and occasionally unites with that vessel.

3. **The Middle Cardiac Vein.**—The middle cardiac vein (**v. cordis media**) (Fig. 750) occupies the posterior interventricular groove, accompanying the right coronary artery. It arises in the vicinity of the apex of the heart and ascends, receiving collateral branches from the posterior surfaces of both ventricles, to open into the coronary sinus near its termination. This, next to the great coronary vein, is the largest vein of the heart, and occasionally opens independently into the right auricle close to the entrance of the coronary sinus.

4. **The Right Coronary Vein.**—The small cardiac or right coronary vein (**v. cordis parva**) (Fig. 750) occupies, when present, the right half of the posterior auriculo-ventricular groove and opens into the coronary sinus just before its termination. Occasionally it opens into the middle cardiac vein, or directly into the right auricle, and is not infrequently lacking as a distinct vessel, the tributaries which empty into it from the posterior surface of the right auricle and the upper part of the posterior surface of the right ventricle then opening directly into the auricle. One of the largest and most constant of these tributaries ascends along the right border of the right ventricle and is termed the **right marginal vein** or **vein of Galen.**

5. **The Oblique Vein of the Left Auricle.**—The oblique vein of the left auricle (**v. obliqua atrii sinistri**), also known as *Marshall's vein*, is a small vein of variable development which descends obliquely over the posterior surface of the left auricle and opens below into the coronary sinus. Above, it is continuous with a fibrous cord contained within the vestigial fold of the pericardium (page 716), the cord and vein together representing the lower part of an original left superior vena cava. The degree of development of the vein varies greatly, and occasionally the fibrous cord retains its original lumen, so that a more or less developed left superior vena cava is really present. This anomaly may, however, be more conveniently considered in connection with those of the superior caval system of veins (page 859).

In addition to these principal veins of the heart there is a varying number of others which open directly into the right auricle and are situated upon the anterior surface of the right ventricle, whence they have been termed the **anterior cardiac veins** (**vv. cordis anteriores**). They are all comparatively short vessels and usually accompany descending branches of the right coronary artery. Owing to the frequency with which it opens directly into the auricle, the vein of Galen is usually regarded as one of this group of veins.

Finally, the **Thebesian veins** (**vv. cordis minimae**) form part of the cardiac venous system. These are minute veins, imbedded in the substance of the heart walls, and communicating with the heart cavities by means of the Thebesian foramina (page 716), which occur most abundantly upon the walls of the right auricle, though also upon those of the left auricle, and, less abundantly, upon those of the ventricles. At their other ends these veins communicate in the heart's substance with the radicles of the other cardiac veins, and, in cases of stenosis of the coronary arteries, may consequently contribute to some extent to the nutrition of the heart musculature, carrying blood to it directly from the heart cavities.

Valves of the Cardiac Veins.—The *Thebesian valve*, which guards the right auricle, may be considered as the ostial valve of that vessel, which throughout its course is destitute of valves. So, too, throughout the extent of the cardiac veins valves are entirely lacking, but certain of those which open into the coronary sinus are provided with ostial valves. That of the great coronary vein is the *valve of Vieussens*, and others are usually present at the mouths of the middle vein and the posterior vein of the left ventricle, and less constantly at the mouths of the marginal and the small coronary veins. These valves may be either single or paired and are frequently insufficient. No valves are present either throughout the course or at the orifice of the oblique vein of the left auricle.

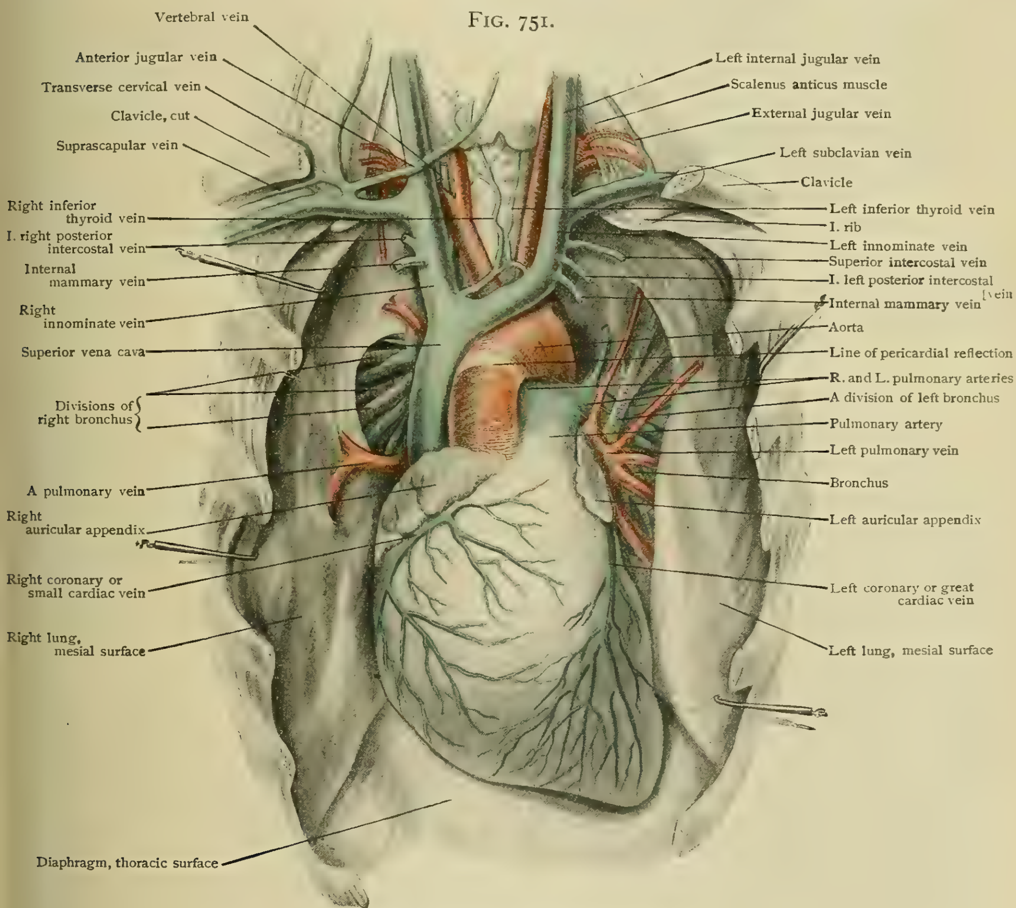
Variations.—The principal variations which occur in connection with the cardiac veins have been noted in the description of the vessels, and it need only be added that the oblique vein of the left auricle is not infrequently entirely lacking, except in so far as it is represented by a fibrous cord, that absence of the great coronary vein has been observed, and that the middle vein occasionally opens directly into the right auricle.

THE SUPERIOR CAVAL SYSTEM.

The Vena Cava Superior.

The superior or descending vena cava (Figs. 749, 751) is the main venous trunk which delivers to the heart the blood returning from the head, neck, upper limbs, and thorax. It measures 7–8 cm. (3 in.) in length, and has a diameter at its termination of about 2.2 cm. (a little less than 1 in.). It is situated throughout its entire course in the thoracic cavity, lying in the superior mediastinum, and is formed immediately

Fig. 751.



Dissection showing innominate veins and superior vena cava in position; lungs have been pulled aside.

below the lower border of the first costal cartilage of the right side by the union of the right and left innominate (brachio-cephalic) veins. Its course is downward and slightly backward, with a curvature corresponding to the first portion of the arch of the aorta, with which it is in relation. Below, it opens into the upper posterior portion of the right auricle on a level with the third costal cartilage of the right side.

Relations.—The lower portion of the superior vena cava is invested by the pericardium to an extent varying from a few to 40 mm., on an average, perhaps to about one-third its length. The upper extrapericardial portion is in relation *anteriorly*

with the thymus gland or the fatty tissue which replaces it, and is overlapped by the right pleura and lung. *Behind*, it crosses the origin of the right bronchus and the structures at the root of the right lung, from which it is separated by numerous lymphatic nodes ; *to the right* it is in contact with the pleura covering the inner surface of the right lung and with the right phrenic nerve ; and *to the left* it lies alongside the ascending portion of the aortic arch.

In its lower intrapericardial portion it has to the left the systemic aorta: *anteriorly*, the right auricle; *posteriorly*, the right pulmonary artery, the right superior pulmonary vein, and the right bronchus, while upon the right it is free.

The vena cava superior contains no valves.

Tributaries.—In addition to the right and left innominate veins, by the union of which it is formed, the vena cava superior receives the vena azygos major and small veins from the mediastinum and pericardium.

Variations.—Cases have been recorded in which the vena cava superior received the right internal mammary or the right superior intercostal vein which normally open into the right innominate vein. It may also receive the vena thyreoidea ima, a vein only occasionally present and draining the territory supplied by the art. thyreoidea ima.

A more remarkable and rarer variation is the union with the superior vena cava of a comparatively large vein which issues from the right lung. A similar condition has been observed in connection with the innominate veins, and its probable significance will be considered in connection with the variations of those vessels.

Practical Considerations.—The superior vena cava would be involved in a stab-wound passing through either the first or the second intercostal space on the right side, close to the sternum. The vessel is subject to compression in aneurism of the ascending aorta (*q.v.*), producing venous congestion in the veins of the neck and of the upper extremities.

THE INNOMINATE VEINS.

The innominate or *brachio-cephalic* veins (**vv. anonymae**) (Fig. 751) are two in number, a right and a left. They are situated in the upper portion of the thoracic cavity, being formed by the union of the internal jugular and subclavian veins, and terminate by uniting opposite the first costal cartilage of the right side to form the vena cava superior. The union of the internal jugular and subclavian vein takes place on each side opposite the sternal end of the clavicle ; but, since the vena cava superior lies entirely to the right of the median line of the body, the left innominate vein has a much greater distance to traverse in order to reach its point of termination than has the right one, and consequently it will be necessary to describe each vein separately.

The **right innominate vein** has a length of 2–4 cm. (¾–1½ in.) and an almost vertical course, opening directly downward into the vena cava superior. It lies behind the inner end of the right clavicle, from which it is separated by the lower portions of the sterno-hyoid and sterno-thyroid muscles, and a little lower it is behind the first right costal cartilage. To the right it is in relation with the inner surface of the right pleura and with the right phrenic nerve, to the left with the brachio-cephalic artery and right pneumogastric nerve, and behind with the pleura.

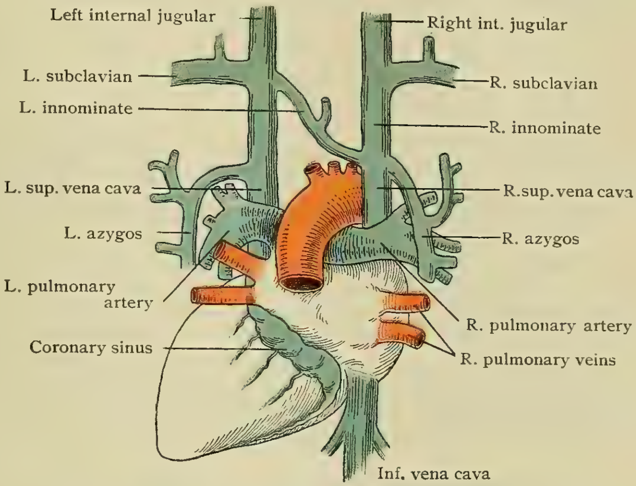
The **left innominate vein** has a length almost double that of the right, measuring 5–9 cm. (2–3½ in.) from its origin behind the sternal end of the left clavicle to its union with the right vein to form the vena cava. Its course is transverse from left to right and at the same time slightly downward, and it extends completely across the uppermost part of the thoracic cavity, resting below upon the aortic arch, and passing in front of the left subclavian and common carotid arteries, the trachea, the brachio-cephalic artery, and the pneumogastric nerve. It is separated from the manubrium sterni by the insertion of the sterno-hyoid and sterno-thyroid muscles and by the fatty tissue representing the thymus gland, and, being on a level with or slightly above the upper border of the manubrium, it can usually be felt in the suprasternal fossa.

Neither of the innominate veins possesses valves. The left is of somewhat greater diameter than the right, owing to the greater number of tributaries which it receives.

Variations.—As pointed out in the account of the development of the great veins (page 926), there is at one stage a symmetrical arrangement of the vessels which open into the right auricle from above ; in other words, the left internal jugular is continued directly downward from the point where the left subclavian vein opens into it to the auricle, this downward continuation being usually termed the left superior vena cava. Later a cross-connection, the left innominate vein, forms between the right and left jugulars at the root of the neck, and the left superior vena cava then normally undergoes degeneration, traces of it only persisting as the oblique vein of the left auricle and the coronary sinus.

Occasionally this normal progress of events fails to occur, the result being the complete absence or imperfect development of the left innominate vein together with a persistence of the left superior vena cava ; or else, even with the perfect development of the left innominate, there may be a failure of the left superior vena cava to degenerate. Various gradations between the embryonic and adult conditions may occur, and the annexed diagram (Fig. 752) shows the nature of the anomaly. It may be noted that with the persistence of the left superior vena cava there is frequently a retention of the communication with it of the left cardinal vein, which normally becomes the v. hemi-azygos,—a condition which will be more especially considered in connection with the anomalies of the azygos veins (page 893).

FIG. 752.



Posterior aspect of heart and great vessels, showing persistence of left superior vena cava ; (semidiagrammatic).

Practical Considerations. — The left innominate vein, running horizontally just below the upper border of the manubrium, lies immediately above the aortic arch. When the latter is unusually high, and occasionally in children, the vein—especially if engorged—may project above the level of the suprasternal notch and may be endangered during a thyroidectomy, the removal of a tumor, or a low tracheotomy.

Tributaries.—In addition to the subclavian and internal jugular veins, by whose union they are formed, each innominate vein receives (1) the *deep cervical*, (2) the *vertebral*, (3) the *internal mammary*, and (4) the *inferior thyroid* veins of its side. The left innominate vein receives in addition (5) the *superior phrenic*, (6) the *thymic*, (7) the *pericardial*, (8) the *anterior mediastinal*, and (9) the *left superior intercostal* vein. Of these the left superior intercostal vein will be described with the other intercostals.

1. **The Deep Cervical Vein.**—The deep cervical vein (**v. cervicalis profunda**) takes its origin in a plexus situated in the occipital triangle and having also connected with it the vertebral and occipital veins. It passes down the neck, lying between the semispinalis cervicis and the splenius cervicis, and in the upper part of its course accompanies the deep branch of the art. princeps cervicis. Lower down it accompanies the deep cervical branch of the superior intercostal artery and bends slightly outward and forward, passes between the transverse process of the seventh cervical vertebra and the first rib, and opens into the innominate vein either behind the vertebral vein or by a common trunk with that vessel.

Tributaries.—In its course down the neck it receives numerous tributaries from the deeper cervical muscles, and opposite each intervertebral foramen which it passes it makes connections with the vertebral vein and the veins of the spinal canal.

The most important of its tributaries is, however, the **occipital vein**, which arises in a plexus covering the occipital portion of the skull and communicating with branches of the posterior auricular and temporal veins. It passes downward with the occipital artery, pierces the

trapezius muscle near its origin from the superior nuchal line, and enters the suboccipital triangle where it opens into the deep cervical vein. Occasionally, however, it either unites with the posterior auricular vein or opens directly into the external jugular below the posterior auricular. The mastoid emissary vein (page 876) usually opens into one of its branches.

2. **The Vertebral Vein.**—The vertebral vein (v. **vertebralis**) accompanies the artery of the same name through all but the cranial portion of its course, and is usually a single trunk, although frequently it is double or occasionally even plexiform throughout more or less of its course. It arises in the suboccipital triangle from a plexus of small veins with which the occipital and deep cervical veins also communicate, and passes downward through the foramina in the transverse processes of the six (occasionally seven or five or even only four) upper cervical vertebræ. At its exit from the foramen of the sixth vertebra it is continued obliquely forward and downward behind the inferior thyroid artery and the internal jugular vein, and, passing usually in front of, but occasionally behind, the subclavian artery, opens into the innominate vein near its origin.

The opening into the innominate is guarded by a pair of valves. Throughout its course the vein is connected to the periosteum, lining each of the vertebrarterial canals it traverses, by fibrous bands, and in its terminal portion it is adherent to the deep cervical fascia, so that its walls do not collapse even when it is emptied of blood.

Tributaries.—Like the vertebral artery, the vein receives tributaries from the deep muscles of the neck and, at each intervertebral foramen which it passes, communicating branches from the plexuses in the spinal canal on the one hand, and from the posterior spinal plexus and the deep cervical vein on the other. In its terminal portion, after it has issued from the foramen in the transverse process of the sixth cervical vertebra, it receives the **ascending cervical vein**, which arises in the plexus upon the anterior surfaces of the bodies of the upper cervical vertebræ, and accompanies the ascending cervical artery down the neck. Very frequently it also receives, shortly before its termination, the deep cervical vein.

3. **The Internal Mammary Vein.**—The internal mammary vein (v. **mammaria interna**) is formed by the union of the venæ comites of the musculo-phrenic and superior epigastric arteries, and throughout the greater part of its course is double, one stem lying along the outer and the other along the inner side of the artery in its course along the inner surface of the anterior thoracic wall. Opposite the second or third intercostal space the two stems unite, the single vein so formed lying to the inner side of the artery and opening above into the innominate vein of the same side. Numerous valves occur in the course of the vein.

Tributaries.—The tributaries of the internal mammary veins correspond in general with the branches of the internal mammary artery with the exception of the superior phrenic, mediastinal, pericardial, and thymic branches, which usually open independently into the left innominate vein. Its **sternal branches** form plexuses upon both surfaces of the sternum, and so form communication with the vein of the opposite side, and the **anterior intercostal branches** unite with the posterior intercostals (page 896). The **perforating branches** assist in returning the blood from the pectoral muscles, those of the first and second intercostal spaces being larger than the rest in the female, and serving to return a considerable portion of the blood from the mammary gland. By means of the **superior epigastric branches** the internal mammary makes connection with the subcutaneous veins of the abdomen, and, since these are also connected with the epigastric and circumflex iliac branches of the iliac veins, an anastomosis is formed between the superior and inferior caval systems of veins.

4. **The Inferior Thyroid Veins.**—The inferior thyroid veins (**vv. thyreoideae inferiores**) have their origin in a venous plexus (**plexus thyreoideus impar**) which covers the anterior surface and sides of the trachea immediately below the isthmus of the thyroid gland, the vessels which form the plexus issuing from the substance of the thyroid gland, or in some cases being downward prolongations of the branches of origin of the superior thyroid veins. From the plexus two or sometimes three veins descend the neck, following paths quite distinct from those of the inferior thyroid arteries, and open below into the innominate veins, their orifices being guarded by valves. When three veins are present, the odd one occupies a median position and is known

as the **vena thyreoidea ima,** corresponding to the artery of the same name, which, however, need not be present with it. It opens usually into the left innominate vein, but occasionally is prolonged inward to terminate in the superior vena cava.

Tributaries.—The plexus thyreoideus impar receives communications from the **superior thyroid veins** and also has opening into it the **inferior laryngeal veins** (**vv. laryngeae inferiores**) which descend from the larynx. The inferior thyroid veins receive directly branches from the trachea (**vv. tracheales**) and from the œsophagus (**vv. œsophageae**).

Practical Considerations.—An incision across the inferior thyroid vein, whose walls, being imbedded in inflamed tissue, could not collapse, has caused sudden death by the entrance of air. Parise, in attempting to seize the divided inferior thyroid vein during tracheotomy, lifted the superficial wall only, thus permitting air to enter the vein with a fatal result (Allen).

5. **The Superior Phrenic Vein.**—The superior phrenic vein (**v. phrenica superior**) has its origin upon the upper surface of the diaphragm and ascends through the thorax, lying between the pericardium and pleura and accompanying the phrenic nerve and the superior phrenic artery, of which it is a companion vein. Usually the veins of both sides are double. They open above into the left innominate vein, frequently uniting with the thymic, pericardial, and mediastinal veins before their termination. They are provided with valves both at their orifice and along their course.

6. **The Thymic Veins.**—The thymic veins (**vv. thymicae**) are rather insignificant in the adult and are usually two or three in number. They arise in the adipose tissue which replaces the thymus gland and empty above into the left innominate vein, frequently uniting with the superior phrenic veins. In the child they are of considerable size in correlation with the development of the thymus gland.

7. **The Pericardial Veins.**—The pericardial veins (**vv. pericardiacae**) vary considerably in number. They are all small, and empty in part into the left innominate vein and in part into the azygos and internal mammary veins.

8. **The Anterior Mediastinal Veins.**—The anterior mediastinal veins (**vv. mediastinales anteriores**), like the preceding, are variable in number and small. They arise in the anterior mediastinum and open above into the left innominate vein.

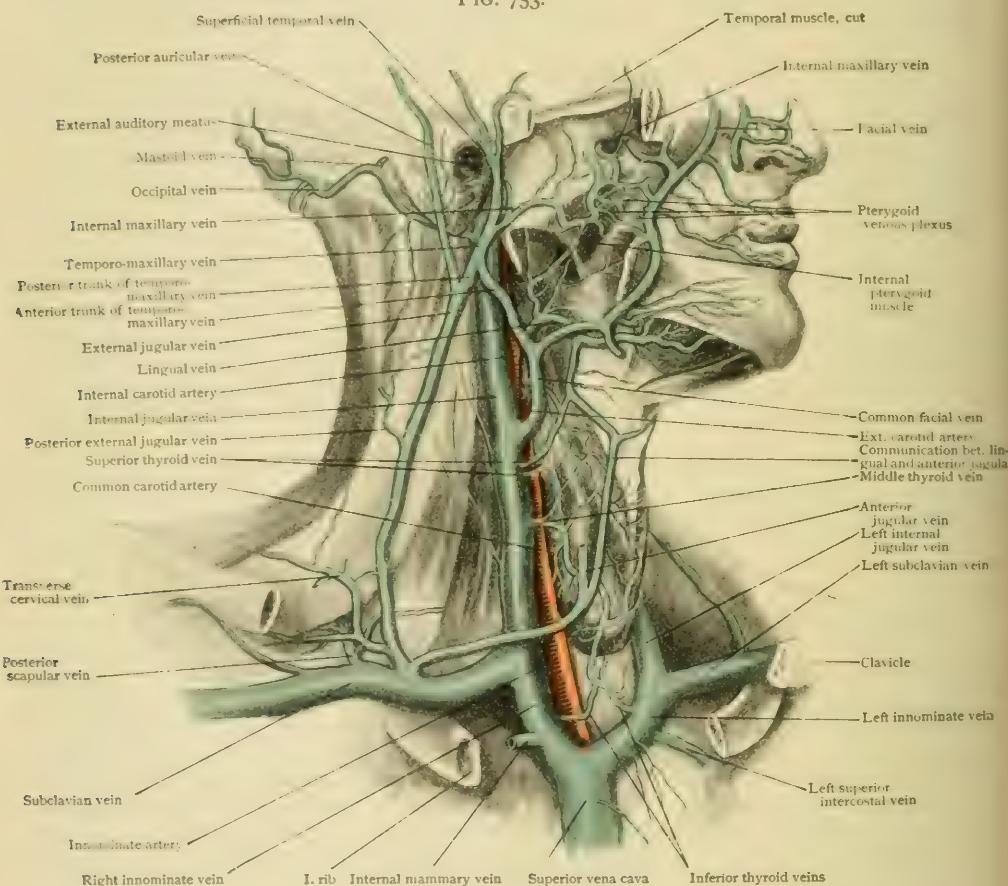
The Internal Jugular Vein.

The internal jugular vein (**v. jugularis interna**) (Figs. 753, 760) is the principal venous trunk of the neck. It is the continuation of the lateral sinus at the jugular foramen, and descends the neck in company with the internal and common carotid arteries to a point a little external to the sterno-clavicular articulation, where it unites with the subclavian to form the innominate vein. At its origin it rests upon the anterior sloping surface of the jugular process of the occipital bone, and usually presents at this point a distinct bulbous enlargement (**bulbus venae jugularis superior**) measuring about 1.5 cm. in diameter. Below the bulbus superior, at its exit from the jugular foramen, the diameter of the vein averages about 9 mm., although subject to considerable variation, and usually differing on the two sides, since the lateral sinuses, of which the veins are the continuations, differ on the two sides, that of the right being in the majority of cases the larger. As it descends the neck the vein gradually increases in size as it receives its various tributaries, and just before its union with the subclavian vein it presents a more or less pronounced spindle-shaped enlargement (**bulbus venae jugularis inferior**). This dilatation is usually much more distinct in the right vein than in the left, and at its upper end is provided with a pair of valves or else with a single one, the cavities of the valves being directed downward as if to prevent an upward flow of blood. Even when a pair is present they are insufficient, but they may nevertheless play an important part in preventing the blood from flowing into the innominate through the subclavian vein and from producing, during the systole of the auricle, a back pressure in the cerebral veins which are in connection with the internal jugular. Since the right innominate is much more nearly in a line with the vena cava superior than is the left, the greater development of the inferior bulb in the right internal jugular can be readily understood.

Relations.—In the upper part of its course the internal jugular rests upon the rectus capitis lateralis and the transverse processes of the upper cervical vertebræ. To its inner side and somewhat in front of it is the internal carotid artery, the glosso-pharyngeal, pneumogastric, spinal accessory, and hypoglossal nerves separating the two vessels above. The external branch of the spinal accessory crosses it obliquely either in front or behind, and somewhat lower it is crossed anteriorly by the stylo-hyoid muscle and the posterior belly of the digastric and also by the occipital and posterior auricular arteries. To its inner side is the wall of the pharynx, with which it is not, however, directly in contact.

Throughout the neck it lies beneath the sterno-cleido-mastoid muscle, immediately to the outer side of the common carotid artery, being enclosed in a common

FIG. 753.



Dissection showing deep veins of neck and head.

sheath with it, as is also the pneumogastric nerve, which lies behind and between the two vessels. Below the omohyoid muscle the vein tends to separate from the artery, passing somewhat more anteriorly. In this part of its course it, or, to be more precise, the inferior bulb, is situated immediately behind the space which separates the two heads of the sterno-cleido-mastoid. Behind, it rests upon the inner border of the scalenus anticus, crosses the subclavian artery, and has the pneumogastric and phrenic nerves passing downward on either side.

Variations.—Variations of the internal jugular vein are not numerous. It may be noted, however, that in its course down the neck it occasionally overlaps the carotid artery to a considerable extent,—a condition which is especially marked in the region of the inferior bulb when this is well developed.

The left internal jugular has been observed much reduced in size, there being a compensatory enlargement of the corresponding external jugular, and it may be doubled throughout a greater or less portion of its course, although always single at either extremity. In addition to the normal tributaries described below, it may receive the temporo-maxillary vein, the vertebral, superior laryngeal, or left superior intercostal, a bronchial vein, the suprascapular, or the transverse cervical vein.

Practical Considerations.—The internal jugular vein—the largest of the superficially placed veins of the body—may be involved in cut-throat or other wounds of the neck. Like the carotid, it usually escapes in attempts at suicide on account of the usual position assumed—with the chin elevated and the head thrown back so that the muscles are rendered tense and prominent and the vessels are protected. If the wound is above the thyroid cartilage they are still safer on account of their inclination backward, and such a wound may reach the spinal column without injuring them. In wounds below the thyroid if the air passages are opened in attempted suicide, the sudden exit of air from the lungs, accompanied by collapse of the chest, may, it has been suggested, result in the dropping of the arm carrying the weapon before the wound has reached the level of the vessels, although they are here more vulnerable than they are above. The internal jugular, the other veins of the neck, and the subclavian and axillary veins, are greatly influenced by respiration, emptying during inspiration, distending during expiration—the "respiratory wave," or "venous pulse." Their attachments to the fascia keep them from entirely collapsing. This is especially noticeable in the internal jugular. After the carotid sheath has been opened the vein will vary in appearance from a distended thin-walled tube perhaps half an inch in diameter, (expiration), to a flaccid, ribbon-like structure with walls apparently in contact (inspiration). During inspiration air may thus be readily drawn into one of these veins if it has been wounded, and if the wound is dry, or if pressure is not immediately applied to the vein on the cardiac side of the wound. If the air is in large quantity it may cause instant death when it reaches the right auricle by over-distension and paralysis of the right side of the heart ; or sometimes less rapidly by asphyxia following air embolism of the pulmonary veins.

The internal jugular vein may be infected secondarily to infective intracranial sinus thrombosis, especially of the sigmoid. Phlebitis or thrombosis of the internal jugular is attended by pain and tenderness along the course of the vein, and later by the development of a cord-like mass to the inner side of the sterno-mastoid muscle and the outer side of the carotid artery. This may involve the whole length of the vein but is apt to be confined to the upper third. When an infected thrombus in the sigmoid sinus has undergone such extensive disintegration that it is unlikely to be entirely removed by operative obliteration of the upper two-thirds of the sinus, or when in a thrombosed internal jugular, giving the sensation of a hard cord-like structure, its upper part becomes soft from disintegration of the thrombus and this disintegration descends, ligation of the vessel below this point usually becomes necessary (Macewen). The ligation shuts off the main channel between the sigmoid sinus and the lungs, although the latter may still be infected by way of the occipital sinus and condylar veins and the subclavian vein.

The vessel is approached by the same incision as that made for ligation of a carotid. The vascular sheath is opened well to the outer side so that the carotid compartment may, if possible, be left intact. The vein should be tied in two places and divided between the ligatures.

After occlusion of the vein either by ligature or by pressure from a growth, the blood from the corresponding side of the head passes by a transverse vein to the internal jugular of the opposite side.

Tributaries.—In addition to the lateral and the inferior petrosal sinuses, which will be described with the other cranial sinuses, the internal jugular receives the following tributaries : (1) the *pharyngeal*, (2) the *facial*, (3) the *lingual*, (4) the *superior thyroid*, and (5) the *middle thyroid* veins.

1. **The Pharyngeal Veins.**—The pharyngeal veins (vv. pharyngeae) are small vessels, varying in number, which open, either independently or after having united to a single stem, either directly into the internal jugular or indirectly by way of the

lingual or superior thyroid vein. They take their origin from a venous plexus (**plexus pharyngeus**) which covers the outer surface of the pharynx, lying between the constrictor muscles and the pharyngeal portion of the bucco-pharyngeal fascia. In addition to branches from the pharyngeal wall, this plexus also receives tributaries from the anterior recti and longus colli muscles, and from the soft palate, the tonsillar plexus and the Eustachian tube, and has opening into it branches from a plexus which surrounds the internal carotid artery in its course through the carotid canal, communicating above with the cavernous sinus. It also receives the veins (**vv. canalis pterygoidei**) which accompany the Vidian artery through its canal, and communicates with the pterygoid, œsophageal, and vertebral plexuses.

2. **The Facial Vein.**—The facial vein (**v. facialis anterior**) (Fig. 754) is formed at about the inner extremity of the eyebrow by the union of the frontal and supraorbital veins. From its point of origin it skirts around the inner border of the orbit and is then directed obliquely downward and backward across the face, crosses over the anterior inferior angle of the masseter muscle and the ramus of the mandible a short distance in front of the angle, and is thence continued onward across the posterior part of the submaxillary and the upper part of the superior carotid triangles to open into the internal jugular at about the level of the hyoid bone. It follows in a general way the course of the corresponding artery, lying posterior to it, but the path across the face is much more direct than that followed by the artery.

That portion of the vein which extends from the junction of the frontal and supraorbital arteries to the lower border of the orbit is usually termed the **angular vein,** and branches arise from this which pass backward into the orbit to communicate with the ophthalmic vein. Just below the ramus of the mandible it usually receives a large communicating branch from the external jugular, and the portion which intervenes between this communication and the internal jugular is termed the **common facial vein** (**v. facialis communis**). Both the facial and the angular veins are usually described as being destitute of valves; these structures do occur, however, but they are always insufficient and form no bar to the passage of blood in an inverse direction—*i.e.*, from the facial and angular backward into the ophthalmic veins.

Relations.—The angular vein rests upon the nasal process of the maxillary vein internal to the lachrymal sac. In its upper portion the facial vein lies under cover of the orbicularis palpebrarum, and it also passes beneath the zygomatic muscles, but is superficial to the other muscles of the face. In its inframandibular or cervical portion it lies beneath the platysma in a groove in the submaxillary gland.

Variations.—The upper portion of the facial vein may be greatly reduced in size. Below, it frequently unites with the lingual vein to form a linguo-facial trunk, which may also be joined by the superior thyroid. Instead of opening into the internal jugular, it occasionally passes across the sterno-cleido-mastoid muscle to unite with the external or anterior jugular.

Practical Considerations.—Allen has called attention to the fact that the venous supply of the face differs in some important particulars from that of the trunk and limbs. In the last-named localities, both deep and superficial currents flow in the same direction towards the heart. The facial trunk, however, is not formed by primal venules, as is commonly the case, but by branches communicating with the frontal and supraorbital veins, and by a transverse branch found at the bridge of the nose.

The two most important communications with the cavernous sinus are through the ophthalmic vein, which receives tributaries from the angular vein, and the deep facial vein, which empties into the pterygoid plexus, which in its turn communicates with the cavernous sinus by veins passing through the foramen ovale. The veins corresponding to the deep parts of the face, other than those mentioned, also seek an outlet in the same direction, so that much of the superficial blood of the upper part and side of the face passes *inward* to the brain-case and to the interior of the facial region, while the remaining portion flows *downward* to join the jugular veins.

The facial vein at its lower end receives a large communicating branch from the external jugular, and therefore at or below that point carries a considerable volume of blood, making wounds of the vein dangerous.

The facial vein is said to be less flaccid than most superficial veins, and therefore to remain more patent after section ; it possesses either imperfectly developed or rudimentary valves, or none at all. As a consequence of these facts, septic disease—malignant pustule, furuncle, carbuncle, cancrum oris—involving the face or forehead, is exceptionally dangerous, as the infection may spread by way of the ophthalmic vein or the pterygoid plexus to the cavernous sinus and result in a fatal thrombosis or meningitis.

The relations existing between the venous blood of the face and that of the brain-case are rendered evident by the fact that the state of the circulation of the external nose is sometimes an index of the condition of the vessels of the brain. Moreover, in cases of orbital or intracranial tumors, the ophthalmic, angular, and facial veins become congested, dilated, and tortuous from pressure-interference with the venous current.

The line of the facial vein is from the canthus of the eye to a point on the mandible at the anterior border of the masseter muscle and just behind the facial artery. This line is straight instead of tortuous, as is the case with that of the latter vessel.

Tributaries.—The tributaries of the facial vein are (a) the *frontal* and (b) the *supraorbital*, by the union of which it is formed. In addition it receives in its course across the face (c) the *palpebral*, (d) the *lateral nasals*, (e) the *superior labial*, (f) the *inferior labial*, (g) the *deep facial*, (h) the *masseteric*, and (i) the *anterior parotid* veins. In its cervical portion it has opening into it (j) the *inferior* or *descending palatine*, and (k) the *submental* veins.

(a) The **frontal veins** (**vv. frontales**) descend over the forehead on either side of the median line, lying immediately beneath the skin upon the frontalis muscle. The branches from which they take origin communicate at the sides and vertex of the skull with tributaries of the occipital and temporal veins, and also through small foramina in the frontal bone with the superior longitudinal sinus. The two veins are connected by numerous cross-branches, and not infrequently unite more or less completely to form a single median stem which bifurcates below. Each vein terminates at the inner angle of the orbit by uniting with the corresponding supraorbital vein to form the angular.

At the root of the nose the two veins are usually united by a distinct cross-branch, the *nasal arch*, which receives from below the dorsal nasal veins.

(b) The **supraorbital vein** (**v. supraorbitalis**) is a relatively large trunk which runs transversely above the superior margin of the orbit and consequently is quite distinct from the artery of the same name. It arises at the external angle of the orbit, where it communicates with affluents of the temporal veins, and passes inward beneath the orbicularis palpebrarum, and, piercing that muscle just above the inner angle of the orbit, unites with the frontal vein to form the angular.

It receives numerous small branches from neighboring regions and from the diploic vein of the frontal bone, and at the supraorbital notch it communicates with the ophthalmic system of veins.

(c) The **palpebral veins** (**vv. palpebrales superiores et inferiores**) are small vessels which take their origin from the venous plexus of the eyelids and open into the angular vein. The palpebral plexus also communicates laterally with the affluents of the temporal veins.

(d) The **lateral nasal veins** (**vv. nasales externae**) arise in a rich plexus which occupies the alæ and tip of the nose and with which the dorsal nasal vein communicates and also branches from the extensive pituitary plexus, these latter branches emerging along the line of junction of the nasal bones and cartilage. The veins extend upward and backward and open into the lower part of the angular vein.

(e) The **superior labial or coronary vein** (**v. labialis superior**) takes its origin in a plexus in the substance of the upper lip with which branches from the septum and alæ of the nose communicate. The course of the vein is independent of that of the artery of the same name, passing backward and somewhat upward to the naso-labial groove, and opening into the facial vein about opposite the ala of the nose.

(f) The **inferior labial vein** (**v. labialis inferior**) arises from a venous plexus in the lower lip and passes downward and outward to open into the facial just after it has crossed the ramus of the mandible. Usually a second vein, the *inferior coronary*, also arises from the inferior labial plexus and passes almost horizontally outward to open into the facial a little below the angle of the mouth.

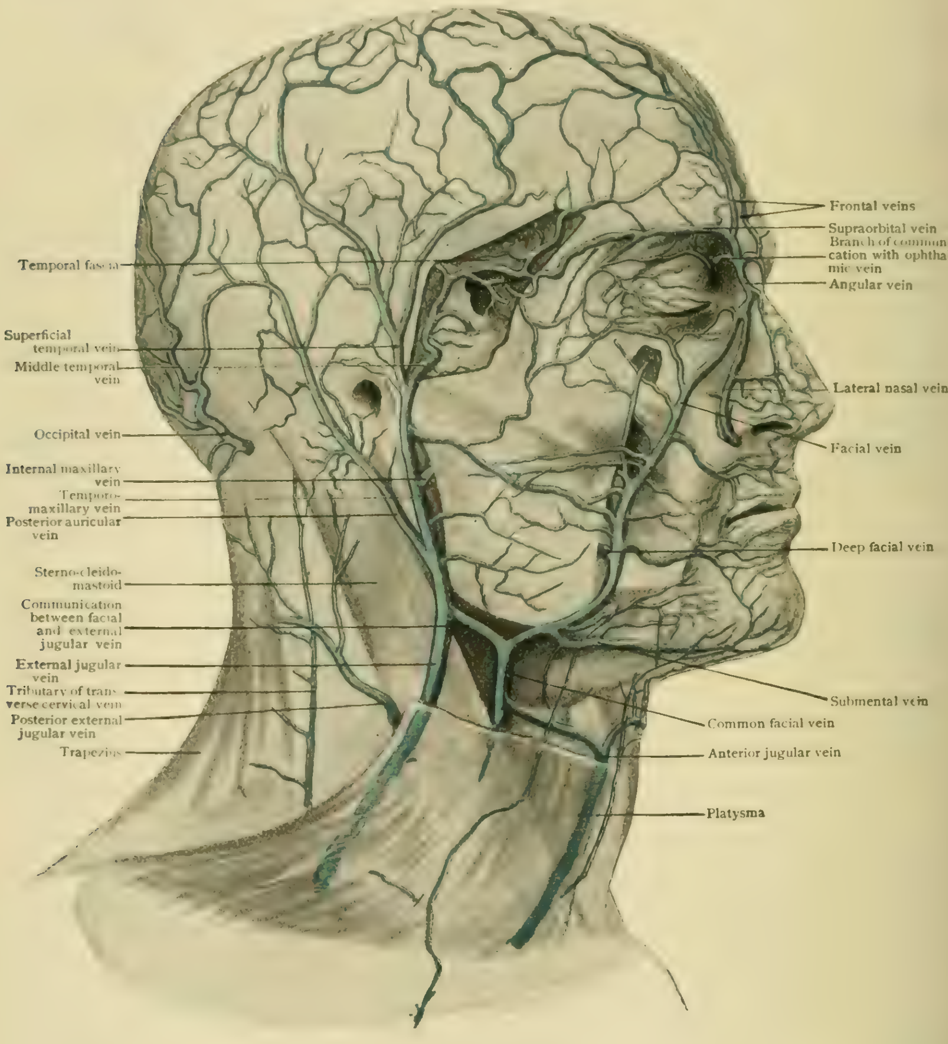
(g) The **deep facial vein**, also termed the *anterior internal maxillary*, takes its origin from the pterygoid plexus (page 882) over the tuberosity of the maxilla, through which it receives branches from a net-work lying beneath the mucous membrane lining the antrum of Highmore. It passes forward and downward between the buccinator and masseter muscles, and opens into the outer surface of the facial where that vein passes beneath the zygomatic muscle.

(*h*) The **masseteric veins** (**vv. massetericae**) are several small veins which return the blood from the masseteric and buccinator muscles, opening into the outer surface of the facial vein.

(*i*) The **anterior parotid veins** (**vv. parotideae anteriores**) consist of several small veins which issue from the anterior border of the parotid gland and from the socia parotidis. They follow the parotid duct, around which they form a net-work, and open into the outer surface of the facial vein.

(*j*) The **inferior or descending palatine vein** (**v. palatina**) accompanies the ascending palatine or tonsillar branch of the facial artery. It takes its origin in the tonsillar plexus and descends upon the side of the pharynx to open into the facial after it has crossed the ramus of the mandible.

Fig. 754.



Superficial veins of head and neck; external jugular lies beneath platysma muscle, which has been partly removed.

(*k*) The **submental vein** (**v. submentalis**) accompanies the artery of the same name. It rests upon the superficial surface of the mylo-hyoid muscle and passes backward and outward in the submaxillary triangle, beneath the platysma, to open into the cervical portion of the facial. It communicates with the sublingual vein by several branches which perforate the mylo-hyoid muscle, and, in addition to cutaneous and muscular branches, also receives tributaries from the submaxillary gland, these latter vessels, however, frequently opening directly into the facial as it traverses the groove upon the gland.

3. **The Lingual Vein.**—The lingual vein (**v. lingualis**) is a short trunk which either opens directly into the internal jugular or unites with the facial vein to form a linguo-facial trunk. It is formed by the union of two vessels, the deep lingual veins, which are the venæ comites of the lingual artery, and the sublingual.

The **deep lingual veins** are of small calibre and accompany the lingual artery throughout its entire course, numerous cross-connections between them involving the artery as in a plexus. Shortly before opening into the lingual stem the two veins unite, and into the vessel so formed the companion veins of the dorsal artery of the tongue (**vv. dorsales linguae**) open, these vessels communicating with the tonsillar plexus and the superior laryngeal vein.

The **sublingual vein,** also termed the *ranine*, has its origin on the under surface of the tip of the tongue, beneath the mucous membrane. It passes backward, at first in company with the submaxillary duct, and, after receiving communicating branches from the deep lingual and the submental veins, it passes to the outer side of the hyoglossus muscle and continues backward in company with the hypoglossal nerve, whence it has been termed the **v. comitans n. hypoglossi.**

All the branches of the lingual vein are provided with valves.

Variations.—Considerable variation exists in the extent to which the lingual vein is developed, both its constituent tributaries as well as the dorsales linguæ sometimes opening independently into the internal jugular. It may open into either the external or anterior jugular instead of the internal, and the deep linguals may open into the pharyngeal vein. Occasionally, by the enlargement of the connection normally occurring, the submental vein becomes a tributary of the sublingual.

4. **The Superior Thyroid Vein.**—The superior thyroid vein (**v. thyreoidea superior**) accompanies the artery of the same name. It arises in the upper portion of the plexus which encloses the thyroid gland, communicating through it with its fellow of the opposite side and with the middle and inferior thyroid veins. It is directed upward and backward, and opens either directly into the internal jugular or more usually into the lingual or the linguo-facial trunk.

Tributaries.—The following are received by the superior thyroid vein. (*a*) The **superior laryngeal vein** (**v. laryngea superior**), which arises in the pharyngo-laryngeal recess from a plexus which receives the blood from the aryepiglottidean fold and the laryngeal musculature and communicates with the vv. dorsales linguæ above and also with the lower portion of the pharyngeal plexus. It passes upward and backward in company with the corresponding nerve and artery and opens into the superior thyroid vein or occasionally into the linguo-facial trunk or the anterior jugular. (*b*) The **crico-thyroid vein** is a slender vessel which accompanies the artery of the same name. (*c*) The **sterno-mastoid vein** (**v. sternocleidomastoidea**) receives blood from the sterno-cleido-mastoid muscle and is associated with the artery of the same name.

5. **The Middle Thyroid Vein.**—The middle thyroid vein is not always present and may be regarded as accessory to the superior thyroid. It issues from the thyroid plexus, opposite the lower part of the lateral lobe of the gland, and passes downward and outward, independently of any artery, to open into the internal jugular at the junction of its middle and lower thirds.

The Sinuses of the Dura Mater.

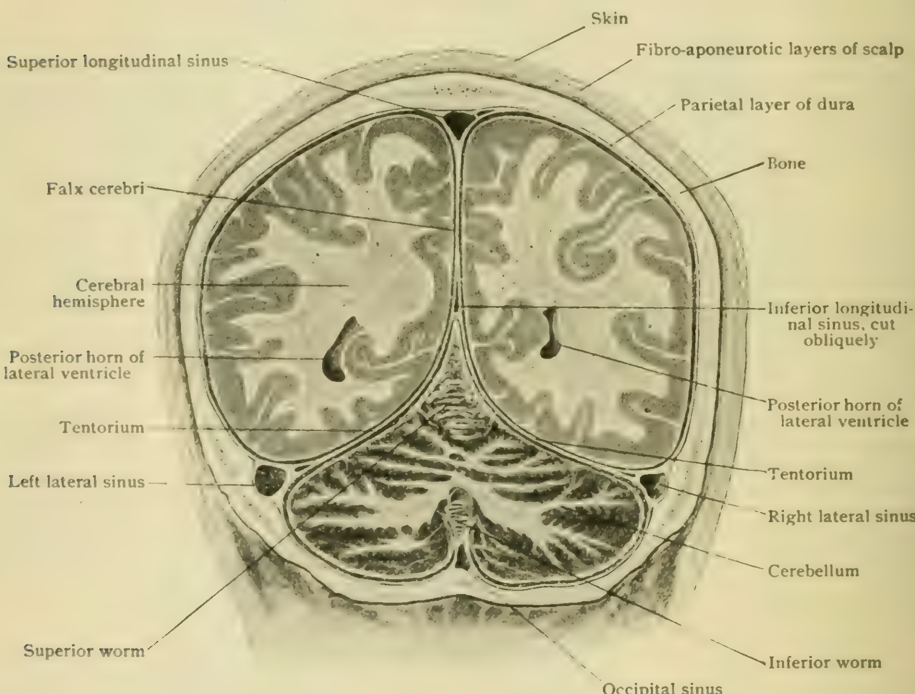
The sinuses of the dura mater (**sinus durae matris**) form a series of channels, frequently of considerable size, occupying clefts in the substance of the dura mater. They receive the cerebral, meningeal, and diploic veins and, in addition, communicate with the extracranial veins by numerous connecting veins known as emissary veins, the largest and most important of which are the ophthalmic veins. They are drained mainly by the internal jugular. A statement of their general structure and a brief description of the blood-lakes associated with them have already been given (page 851).

1. **The Lateral Sinus.**—The lateral sinus (**sinus transversus**) (Figs. 756, 757) has its origin opposite the internal occipital protuberance, at which point there is a meeting of five sinuses, the two lateral, the superior longitudinal, the straight, and

the occipital. From this meeting-point, which is termed the *torcular Herophili* (**confluens sinuum**), each lateral sinus passes outward over the squamous portion of the occipital bone along the line of the attachment of the tentorium cerebelli, and, passing over the posterior inferior angle of the parietal, is continued inward upon the inner surface of the mastoid portion of the temporal and the jugular process of the occipital to reach the jugular foramen, where it opens into the internal jugular vein. As it passes upon the mastoid portion of the temporal, it leaves the line of attachment of the tentorium cerebelli, passing somewhat downward as well as inward, and follows the line of junction of the petrous and mastoid portions of the bone in a somewhat S-shaped course, whence this portion of it is frequently termed the *sigmoid sinus*.

A difference in size is usually noticeable in the sinuses of the opposite sides, that of the right being usually the larger, and this difference is due to the mode in which the various sinuses meet at the torcular Herophili. Most frequently the superior longitudinal sinus communicates mainly with the right lateral, while the

FIG. 755.



Frontal section of head, viewed from behind, showing relations of dura mater to sinuses and to cerebral hemispheres and cerebellum.

straight sinus opens principally into the left, the greater amount of blood carried by the superior longitudinal, as compared with that transmitted by the straight, resulting in the larger size of the right lateral sinus. Indeed, in some cases the right lateral sinus is practically the direct continuation of the superior longitudinal and the left lateral of the straight, the two laterals being connected only by a short and relatively small connecting arm, which represents the torcular Herophili. Throughout that portion of their courses in which the lateral sinuses lie in the line of attachment of the tentorium cerebelli they are triangular in cross-section (Fig. 755), but in their mastoid (sigmoid) portion they are semi-circular; the right sinus has a diameter of from 9–12 mm., while the left varies from 3–5 mm. At the jugular foramen each sinus makes a sudden bend and opens either directly into the summit of the superior jugular bulb, or else at a varying distance downward upon the anterior surface of the bulb, the upper extremity of which then forms a dome-shaped structure projecting upward into the jugular foramen.

Tributaries.—The lateral sinuses, in addition to the sinuses which communicate with them at the torcular Herophili, receive the following tributaries, most of which will be described in greater detail later: (*a*) the **posterior inferior cerebral veins**, which pass backward from the temporo-sphenoidal regions of the cerebral hemispheres; (*b*) some of the **inferior cerebellar veins**; (*c*) the **superior petrosal sinus**, this latter communicating with it just where it leaves the line of attachment of the tentorium cerebelli. Into the sigmoid portion there open (*d*) the **internal auditory veins** (**vv. auditivae internae**), which issue from the internal auditory meatus; (*e*) the **mastoid emissary vein** (page 876); and (*f*) some of the veins of the medulla oblongata and pons.

Variations.—Considerable variation exists in the relative sizes of the right and left lateral sinuses, in accordance as the superior longitudinal sinus opens more or less directly into one or the other. As stated, the tendency is for the superior longitudinal to open into the right lateral; quite often, however, it opens into the left, and occasionally it may communicate equally with both. In 100 crania, Rüdinger found that the right lateral sinus was the larger in 70 cases, the left in 27, and the two were equal in size in only 3 cases.

The horizontal portion of the left sinus has been observed to be lacking or reduced to an exceedingly fine channel, and one or both of the sinuses have been observed to pass through a greatly enlarged mastoid foramen to open into the posterior auricular vein, the sigmoid sinus being represented only by a very small channel.

In a considerable number of cases a small sinus, known as the *petro-squamosal sinus*, opens into the lateral just as it bends downward and inward upon the mastoid portion of the temporal. This sinus passes downward over the anterior surface of the petrous portion of the temporal, along the line of its junction with the squamous portion, and occasionally passes through a foramen—the foramen jugulare spurium—which opens to the exterior just behind the articular eminence of the zygomatic process. The sinus represents the original terminal portion of the lateral sinus, the sigmoid portion of that sinus being a secondary formation, and opened after its exit from the foramen jugulare spurium into the internal jugular, although its connection in the adult is with the temporal vein.

Practical Considerations.—By reason of its proximity to the middle ear, mastoid antrum and cells, the *sigmoid portion* of the lateral sinus is more often the subject of thrombosis than any other sinus (page 1509). This may arise in the following six ways, mentioned in the order of frequency, the first outnumbering all the others: (1) Extension from chronic purulent inflammation of the middle ear; (2) extension of acute inflammatory disease from the mouth, pharynx, and tonsils into the middle ear, antrum, and cells; (3) extension of thrombosis from other sinuses, especially the so closely associated superior petrosal; (4) trauma, such as fracture of the base extending through the middle ear to the sinus; (5) pressure of tumors or discharge associated with them; (6) infection from septic wounds of the head, neck, or mastoid region (Macewen).

The anatomical symptoms of thrombosis of this sinus may be due to (*a*) obstructive distension of the superficial veins communicating with the sinus, chiefly the mastoid vein (*q.v.*); (*b*) mastoid inflammation (osteitis) resulting from contiguity and from the venous connection; (*e*) phlebitis of the veins communicating with the sinus, especially the internal jugular (page 863), condyloid (page 876), and, occasionally, the mastoid.

The subject of sigmoid sinus thrombosis is further considered in relation to the mastoid (page 1508).

The *knee* (genu) of the sigmoid portion of the lateral sinus extends further inward and forward on the right side than on the left, and this fact, together with the larger size of the right lateral sinus as compared with the left, aids in explaining the greater frequency of sinus thrombosis, septic meningitis, and cerebral abscess as sequelæ of otitis media on the right side (page 1509). The infection is carried by the veins which connect the mastoid cells and antrum with the genu of the sigmoid sinus.

On the surface the top of the curve represented by the horizontal and descending (sigmoid) portion of the lateral sinus should correspond to a point (asteric) 2.5 cm. above and 3.8 cm. ($1\frac{1}{2}$ in.) behind the centre of the auditory meatus. This is about the infero-posterior parietal angle. The superior limit of the horizontal portion of the sinus is represented by a line from this asteric point to 3.8 cm. ($1\frac{1}{2}$ in.) above the inion. The superior and anterior boundary of the sigmoid portion is indicated by a line from the same point curving downward and forward along the skin groove at the auriculo-mastoid junction to a little below the level of the external

auditory meatus. Here the sinus turns inward and forward to reach the jugular foramen and has no further close relation to the lateral cranial wall. A curved line drawn 12 mm. (½ in.) below the horizontal and behind the vertical portions of the curved line last described represents approximately the inferior and posterior boundary of the sinus. The width thus indicated—a half inch—varies; it is usually greater in the descending part of the sinus. So, too, the space intervening between the genu and the posterior wall of the external auditory meatus may vary from 2–12 mm.

The direction of the sinuses is also indicated (Macewen) by a line from the upper edge of the external meatus to the asterion, and by one from the tip of the mastoid to the parieto-squamo-mastoid junction, the latter corresponding to the midportion of the sinus, or that most often involved in middle-ear disease. The region of danger in trephining is enclosed (Birmingham) by two lines, one from a point 3.3 cm. (1¼ in.) above and 3.8 cm. (1½ in.) behind the centre of the external auditory meatus to a point 12 mm. (½ in.) above the inion; the other from a point 3.8 cm. (1½ in.) behind the meatus and on the same level to a point 12 mm. (½ in.) below the inion. The sinus almost never overpasses these limits in either a downward or an upward direction, and hence the trephine or chisel may be safely applied either below or above these lines.

Fracture of the base of the skull may extend into the lateral sinus, in which case the blood may pass outward into the tympanum and thence by way of the Eustachian tube to the pharynx, or—if the tympanic membrane is torn—may find exit, mingled with cerebro-spinal fluid, at the external auditory meatus (page 1505).

For further remarks on the practical relations of this important sinus, see page 1508.

2. **The Superior Longitudinal Sinus.**—The superior longitudinal sinus (**sinus sagittalis superior**) (Fig. 756) is an unpaired sinus which lies along the line of attachment of the falx cerebri to the cranial vault. It begins blindly anteriorly by a small vein-like portion which lies in the foramen cæcum between the frontal and ethmoidal bones, but soon becomes a true sinus which passes upward and backward in the median line of the frontal bone, beneath the sagittal suture of the parietals, and down the median line of the squamous portion of the occipital to terminate at the internal occipital protuberance by opening into the torcular Herophili, or, usually, more or less directly into the right lateral sinus.

The sinus is triangular in section and increases gradually in size from before backward, measuring about 1.5 mm. in diameter at the level of the apex of the crista galli and 11 mm. at its termination. Its lumen is usually traversed by numerous irregular bands of connective tissue known as *chordæ Willisii*, and frequently, especially in aged persons, Pacchionian bodies, which are numerous along its course, project into it (Fig. 1039).

Tributaries.—In the fœtus and in early childhood the superior longitudinal sinus communicates with the veins of the nasal cavity through the foramen cæcum, but this connection is dissolved in the adult. In addition, it communicates with the neighboring blood-lakes and through these with the meningeal veins, and receives (*a*) branches from the adjacent portions of the dura mater; (*b*) the **superior cerebral veins**, from ten to fifteen in number (page 877); and (*c*) **diploic veins**, some of which traverse the parietal bone and constitute emissary veins, the most noticeable of these being one which traverses the parietal foramen (page 876).

Variations.—The superior longitudinal sinus varies considerably in size and is occasionally exceedingly small, the tributaries which normally open into it passing downward in the falx to open into the inferior longitudinal sinus. It has been observed to divide into two trunks throughout a portion of its course, and also to divide at the apex of the occipital bone into two trunks which followed the lines of the lambdoid suture to open into the lateral sinuses. Usually, as stated, the sinus communicates more or less directly with the right lateral sinus, but occasionally it may bend to the left of the internal occipital protuberance and open into the left lateral.

Practical Considerations.—The superior longitudinal sinus may become infected (*a*) from the scalp through the diploic veins; (*b*) from foci of cerebral or meningeal disease through the contiguous blood-lakes or through the cerebral veins; (*c*) in childhood from the nose through the veins traversing the foramen cæcum.

When the latter veins are patent epistaxis may be a symptom of cerebral hyperæmia (as in congestive headaches) and may relieve it. In children epistaxis, in infants œdema of the scalp over the anterior fontanelle, and in adults œdema over the parietal and occipital regions are common symptoms of thrombosis of this sinus, and are easily understood in view of its venous tributaries.

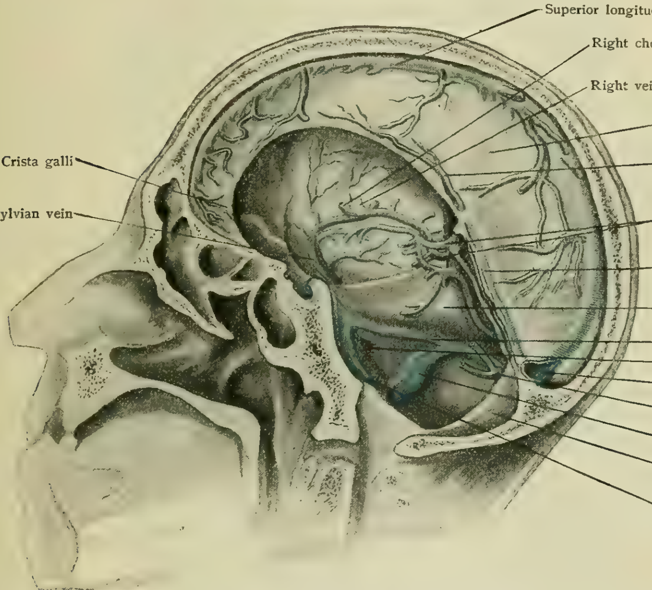
Nævi in the scalp in the mid-line sometimes communicate directly with the sinus by veins passing between the parietals or directly through them near the medial edge.

Traumatic or inflammatory thrombosis may follow a depressed fracture of the cranial vault if the fragment invades the lumen of the sinus and obstructs or arrests the flow of blood.

A noninfective form of thrombosis is sometimes observed in connection with this sinus. It has received the name of *marasmic thrombosis*, as it has usually been associated with weakness and debility.

The construction of all the sinuses predisposes them to thrombosis. Their rigidity, their width, the trabeculæ which occasionally cross them, the peculiar manner in which they are prevented from being too rapidly depleted during inspira-

FIG. 756.



Head has been sectioned to left of mid-sagittal plane and brain removed, showing dural septa in position; terminal portions of some superior cerebral veins are seen upon the surface of falx cerebri.

tion when the lowering of pressure takes place in the great cervical veins (page 878), and, in the case of the longitudinal sinus, the direction in which the blood from the cerebral veins enters at an obtuse or right angle against the current, all tend to retard the flow of blood and favor coagulation. When to these conditions is added a deficient supply of possibly defective blood, as in exhaustion or depletion from profuse diarrhœa, marasmic thrombosis is apt to occur (Macewen).

The line of the sinus begins at the root of the nose and runs in the mid-line to the external occipital protuberance.

Rarely there are found in the mid-line of the vertex small reducible swellings to which are feebly transmitted the brain pulsations. They are subpericranial, contain venous blood, and connect with the longitudinal sinus through apertures in the skull, either congenital, the result of bone disease or atrophy, or due to accident.

3. **The Inferior Longitudinal Sinus.**—The inferior longitudinal sinus (**sinus sagittalis inferior**) (Fig. 756) is an unpaired sinus which lies in the inferior or free edge of the falx cerebri. It begins at about the middle of the border of the falx and passes

backward, gradually increasing in size, to the junction of the falx with the tentorium cerebelli, where it opens into the straight sinus. It receives small tributaries from the falx and sometimes also from the corpus callosum.

4. **The Straight Sinus.**—The straight sinus (**sinus rectus**) (Fig. 756), also unpaired, lies along the line of junction of the falx cerebri with the tentorium cerebelli. It is formed at the anterior border of the tentorium by the junction of the inferior longitudinal sinus and the great cerebral vein (*vena Galeni*) (page 877), and is directed backward to open into the torcular Herophili or more usually into the left lateral sinus.

In addition to the two trunks by whose union it is formed, it receives a number of small branches from the tentorium, branches from the posterior portion of the medial surfaces of the cerebral hemispheres, and sometimes a median superior cerebellar vein.

5. **The Occipital Sinus.**—The occipital sinus (**sinus occipitalis**) (Fig. 757) is an unpaired, or in some cases a paired, sinus which descends from the torcular Herophili along the line of attachment of the falx cerebelli to the posterior border of the foramen magnum. There it divides into two trunks, the *marginal sinuses*, which pass forward along the margin of the foramen magnum, one on one side and one on the other, to open into the bulbus superior of the corresponding internal jugular vein.

The occipital sinus receives as tributaries branches from the falx cerebelli and the adjacent portions of the dura, and also some veins from the inferior surface of the cerebellum. At the posterior border of the foramen magnum, where it bifurcates to form the marginal sinuses, it makes connection with the veins of the posterior spinal plexus.

Variations.—The occipital sinus is occasionally wanting, and frequently extends only as far as the posterior border of the foramen magnum, the marginal sinuses being undeveloped. It may open above into either the right or left lateral sinus, or into the straight sinus a short distance before its termination.

6. **The Cavernous Sinus.**—The cavernous sinus (**sinus cavernosus**) (Fig. 757) is a paired sinus of considerable size which extends along the sides of the body of the sphenoid bone from the sphenoidal fissure in front to the apex of the petrous portion of the temporal. It measures about 2 cm. in length and has a diameter of about 1 cm. and is almost quadrilateral in cross-section. Its external diameter does not, however, represent the actual capacity of its lumen, since this is greatly reduced in size (1) by being traversed by numerous trabeculæ from which fringe-like prolongations hang freely into the blood-current, a section of the sinus having very much the appearance of a section of the corpus cavernosum penis, whence the name bestowed upon it by Winslow; and (2) by the fact that the internal carotid artery and the abducent (sixth) nerve traverse it, while certain other of the cranial nerves are embedded in its outer wall. These nerves are the oculomotor, the pathetic, and the ophthalmic and maxillary divisions of the trigeminus, which lie in that order from above downward.

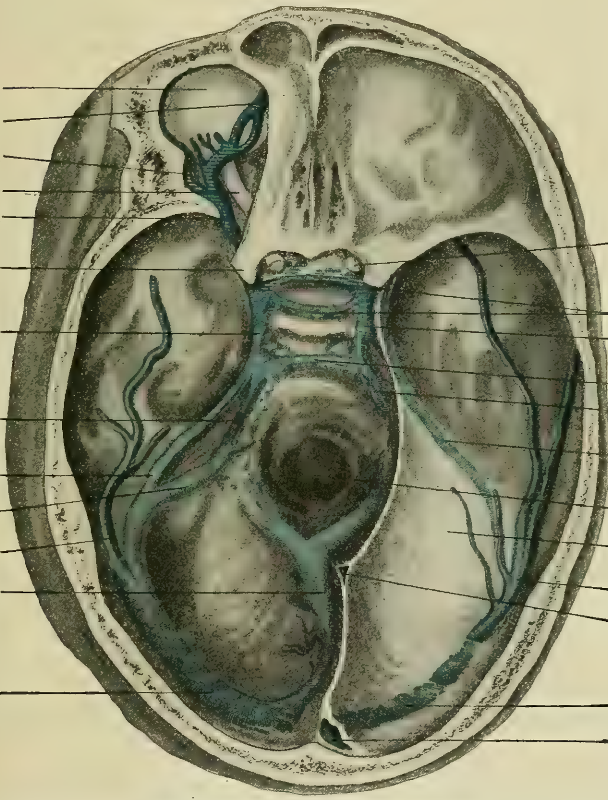
Tributaries.—At the sphenoidal fissure the cavernous sinus receives the ophthalmic vein and, farther back, occasionally the basilar vein, both of which are described later on (page 877). In addition, it receives veins from the neighboring portions of the dura mater, and has connecting with it the spheno-parietal and the **intercavernous sinuses**. These latter are transverse sinuses which pass across between the two cavernous sinuses, the one (**sinus intercavernosus anterior**) passing in front of the sella turcica and the other (**sinus intercavernosus posterior**) behind that cavity, and they receive branches from the dura mater and from the pituitary body. The two sinuses, together with the portion of the cavernous sinus between their terminations on each side, form what is usually termed the **circular sinus** (**sinus circularis**).

Besides the vessels which are truly tributaries, the cavernous sinus also has connected with it certain vessels which are emissary in function, leading blood away from it. The two petrosal sinuses in which it terminates are of this nature. In addition, veins pass from its under surface (1) through the foramen ovale, along with the mandibular division of the trigeminal nerve, to communicate with the pterygoid plexus; (2) through the fibrous tissue which closes the foramen lacerum medium; (3) through the foramen of Vesalius, when this exists; and (4) occasionally through the foramen rotundum with the maxillary division of the trigeminal nerve.

Where the internal carotid enters the cavernous sinus at the internal orifice of the carotid canal the sinus projects downward around the artery in a funnel-shaped manner, and from it there arises a close net-work of veins, the **carotid plexus** or **carotid sinus**, which completely invests the artery throughout its course through the carotid canal, at the lower opening of which it is continued into one or two veins which open into the internal jugular.

Practical Considerations.—The cavernous sinus, though less frequently affected with thrombosis than any other large sinus, may become infected from foci apparently far removed, through the extra-orbital communications of the ophthalmic veins (pages 879, 880). Thus, carbuncle of the face, cancrum oris, alveolo-dental periostitis, ulceration of the Schneiderian mucous membrane, empyema of the maxillary antrum, abscess of the frontal sinus, osteomyelitis of

FIG. 757.



Dural sinuses at base of skull; falx cerebri and left half of tentorium have been removed.

the frontal diploic tissue, may each be followed by cavernous sinus thrombosis. In the presence of thrombosis, there are two groups of pressure symptoms (*a*) venous, causing exophthalmos, œdema of the eyelids and of the corresponding side of the root of the nose, and some chemosis; (*b*) nervous, causing ptosis, strabismus, variations in the pupil, pain, etc.

Arterio-venous aneurism between this sinus and the internal carotid, in addition to similar symptoms of venous obstruction (page 863), often likewise causes paralyses in the distribution of the third, the fourth, and the ophthalmic division of the fifth cranial nerves, which lie in the dura mater on the outer wall of the sinus, and of the sixth nerve, which is in close relation to the internal carotid.

The bulk of the blood of the contents of the anterior and lower portions of the skull empties into the cavernous sinus; that of the remaining portion,—including the greater part of the cerebrum, the cerebellum, the pons, and the cerebral peduncles

—chiefly into the tributaries of the lateral sinus. The two sinuses through the superior petrosal sinus and other venous channels, have free anastomotic connection which effectually tends to equalize or distribute blood-pressure.

The communication between the two cavernous sinuses through the basilar sinus —or plexus—and the circular sinus, is an important portion of the mechanism by which the pressure of venous blood within the skull is equalized. This same communication may, however, in a case of anterio-venous aneurism (*vide supra*) bring about involvement of the orbit on the other side, the blood from the aneurism entering the opposite sinus by way of these intercommunicating sinuses, or infection may follow the same channel.

7. **The Spheno-Parietal Sinus.**—The spheno-parietal sinus (**sinus sphenoparietalis**), also known from its position as the *sinus alæ parvæ*, arises at the outer extremity of the lesser wing of the sphenoid from one of the meningeal veins and passes horizontally inward, under cover of the posterior border of the lesser wing, to reach the cavernous sinus near its anterior extremity. It receives dural, diploic, and some of the anterior cerebral veins.

8. **The Superior Petrosal Sinus.**—The superior petrosal sinus (**sinus petrosus superior**) is the smaller of the two sinuses into which the cavernous divides at the apex of the petrous portion of the temporal. It passes outward and backward along the superior border of the petrous bone and opens into the lateral sinus just at the point where it leaves the line of attachment of the tentorium cerebelli to become the sigmoid sinus. The superior petrosal sinuses receive some small tympanic veins and some branches from the cerebellum and cerebrum.

9. **The Inferior Petrosal Sinus.**—The inferior petrosal sinus (**sinus petrosus inferior**) is the larger terminal branch of the cavernous sinus, and extends from the posterior extremity of that sinus, at the apex of the petrous portion of the temporal bone, along the petro-occipital suture to the jugular foramen, where it opens into the superior bulb of the jugular vein, or, frequently, into the vein below the bulb.

In addition to small branches from the neighboring portions of the dura and from the cerebellum, pons, and medulla oblongata, the inferior petrosal sinus receives some internal auditory veins and an *anterior condyloid vein* which arises from a plexus surrounding the hypoglossal nerve in its course through the anterior condyloid foramen. In its anterior portion the sinus is also in communication with the basilar sinus.

10. **The Basilar Sinus.**—The basilar sinus (**plexus basilaris**), also termed the *transverse sinus*, is usually a plexus of sinuses rather than a single, distinct sinus. It occupies the dura mater which covers the basilar process of the occipital bone and communicates with the inferior petrosal and posterior intercavernous sinuses in front, and behind, at the anterior border of the foramen magnum, with the anterior spinal plexus. It receives branches from the medulla oblongata and from the diploë.

Practical Considerations.—Fracture of the base of the skull through the posterior (cerebellar) fossa may involve the basilar plexus of sinuses and be followed by an intracranial hemorrhage which slowly oozes through the line of fracture and, following the lines of vessels or nerves, ultimately causes swelling and ecchymosis of the skin of the neck ; the latter is apt to show first anterior to the tip of the mastoid, to which region the blood is conducted by the cellular tissue around the auricular artery. It spreads thence upward and backward in a curved line.

The Diploic Veins.

The spaces of the diploë are traversed by a rich plexus of veins, characterized by the thinness of their walls and opening by numerous small communicating branches either into the veins of the scalp, the middle meningeal veins, or the cranial sinuses. Some larger, although rather inconstant, stems also arise from the plexus and form what are termed the diploic veins. Of these, four are usually recognized (Fig. 758).

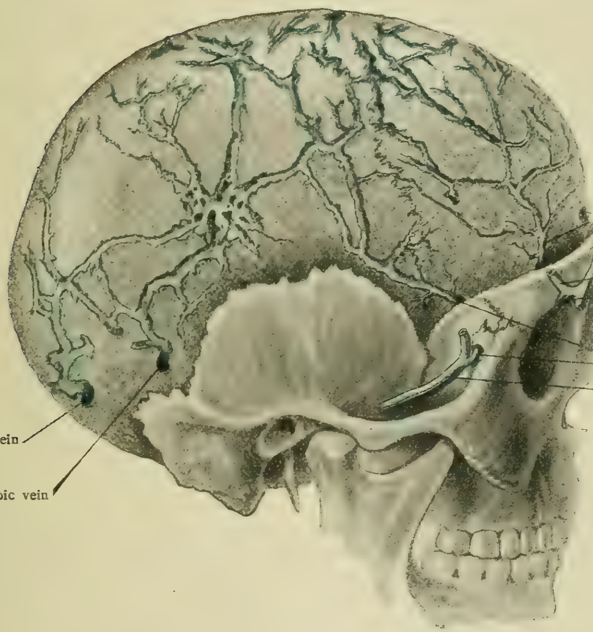
1. The **anterior diploic vein** (**v. diploica frontalis**) descends in the diploë of the frontal bone and at the level of the supra-orbital notch opens either into the supra-orbital or ophthalmic vein. It communicates with the anterior temporal diploic vein and also with the frontal veins and the superior longitudinal sinus.

2. The **anterior temporal diploic vein** (**v. diploica temporalis anterior**) passes downward and forward in the diploë of the anterior portion of the parietal bone and opens either into a deep temporal vein or into the spheno-parietal sinus.

3. The **posterior temporal diploic vein** (**v. diploica temporalis posterior**) passes downward in the diploë of the posterior part of the parietal bone and usually opens into the mastoid emissary vein, thus communicating with the lateral sinus. It also communicates with the posterior auricular vein and may open into it.

4. The **occipital diploic vein** (**v. diploica occipitalis**) passes downward in the squamous portion of the occipital bone, not far from the median line, and opens either into the occipital vein or into the occipital emissary vein, by which it communicates with the torcular Herophili or the lateral sinus.

FIG. 758.



Outer table of skull has been removed to expose venous spaces of diploë.

Practical Considerations.—The diploic veins being incapable of effective contraction, bleed very freely and persistently, and are sometimes a source of embarrassment during operations on the skull. Through their communications with the veins of the scalp on the one hand, and with the endo-cranial sinuses and meningeal veins on the other, they may, as in some cases of compound fracture, convey infection from the surface to the diploë, causing osteomyelitis and necrosis, or within the cranium, causing septic meningitis or sinus thrombosis. Pyæmia has followed an infective phlebitis of the diploic veins themselves. Diploic infection introduced from without—pyogenic—or through the blood—tuberculous—is apt to spread rapidly within the diploic tissue itself, as well as to the underlying structures.

The Emissary Veins.

The term *emissary vein* is applied to those branches which place the sinuses of the dura mater in communication with veins external to the cranial cavity. Using the term in its broadest sense, the emissary veins are very numerous, since both the diploic and the meningeal veins might be regarded as such, as well as the carotid

plexus (page 873) and the ophthalmic vein (page 879), all these making connections with the sinuses, on the one hand, and with extracranial veins, on the other. It is customary, however, to limit the term to certain veins which, for the most part, traverse special foramina in the cranial walls, a few, however, passing through foramina whose principal content is one of the cranial nerves.

1. The **parietal emissary vein** (**emissarium parietale**), rather variable in size, traverses the correspondingly variable parietal foramen, placing the superior longitudinal sinus in communication with the veins of the scalp.

2. The **occipital emissary vein** (**emissarium occipitale**) traverses the occipital protuberance and places the torcular Herophili or one or the other of the lateral sinuses in communication with the occipital veins. Its size is variable; it usually receives the occipital diploic vein, and may perforate only the external or the internal table of the occipital bone, representing in such cases the terminal portion of the diploic vein rather than a true emissary.

3. The **mastoid emissary vein** (**emissarium mastoideum**) passes through the mastoid foramen and places the lateral sinus in communication with either the occipital or the posterior auricular veins. It is occasionally wanting, and, on the other hand, may be so large as to appear to be the continuation of the lateral sinus, the terminal portion of that vessel between the mastoid and jugular foramina being greatly reduced in size.

4. The **posterior condyloid emissary vein** (**emissarium condyloideum**) is very inconstant, and when present traverses the posterior condyloid foramen, extending between the lateral sinus near its termination and the vertebral veins.

5. The **anterior condyloid emissary vein** (**rete canalis hypoglossi**) is a net-work which surrounds the hypoglossal nerve in its course through the anterior condyloid foramen. From the plexus two veins arise, one of which passes to the inferior petrosal sinus and the other to the vertebral veins.

6. The **emissaries of the foramen ovale** (**rete foraminis ovalis**) are formed by two veins which communicate above with the cavernous sinus and pass to the foramen ovale, where they form a plexus surrounding the mandibular division of the trigeminal nerve and communicate with the pterygoid plexus of veins. Occasionally, also, a similar plexus accompanies the maxillary division of the trigeminus through the foramen rotundum.

7. The **emissary vein of the foramen of Vesalius** is, like the foramen, inconstant, occurring only about once in three cases. It extends between the cavernous sinus and the pterygoid plexus of veins.

8. Finally, a variable number of small veins pass through the connective tissue which closes the **foramen lacerum medium** and place the cavernous sinus in communication with the pterygoid plexus.

Practical Considerations.—The relations of the emissary veins explain many cases of spread of extra-cranial infection to the meninges and the sinuses. If there were no emissary veins, injuries and diseases of the scalp and skull would lose half their seriousness (Treves). Infected wounds of the scalp, cellulitis or erysipelas involving that structure, osteomyelitis, or necrosis of the cranial bones may through the emissary veins result in serious intra-cranial disease. The largest of these veins is usually the mastoid, the communication between the lateral sinus and the occipital or posterior auricular vein (*vide supra*). This relation and the considerable quantity of blood carried by the mastoid vein are thought to explain the supposed effect of leeches or blisters applied behind the ear in cerebral hyperæmia or inflammation, especially as nearly all the blood of the brain leaves it through the lateral sinuses. They also explain the extensive œdema behind the ear and around the mastoid region often seen in lateral sinus thrombosis. Pus has formed in the cerebellar fossa outside of the sigmoid sinus, made its exit through the mastoid foramen and appeared as an occipito-cervical abscess (Erichsen). The escape of pus by the mastoid foramen indicates extradural pus in the cerebellar fossa about the sigmoid groove, with the probability that sigmoid sinus thrombosis exists, especially if the mastoid vein is itself thrombosed (Macewen).

In suppurative sigmoid sinus disease the posterior condyloid vein may convey infection to the cellular tissue in the upper part of the posterior cervical triangle, causing abscess beneath the deep fascia; or, as a result of cerebellar pachymeningitis, there may be phlebitis of this vein, with marked tenderness in the same region. The emissary veins are important agents in the equalization of intra-cranial pressure.

THE CEREBRAL VEINS.

The cerebral veins (vv. cerebri) convey the blood carried to the brain by the cerebral arteries to the sinuses of the dura mater. They differ from most of the other veins in that they contain no valves, their walls are very thin and destitute of muscle-tissue, and their arrangement does not usually follow that of the arteries.

1. **The Superior Cerebral Veins.**—The superior cerebral veins (**vv. cerebri superiores**) are from eight to twelve in number, draining the upper, lateral and medial surfaces of the cerebral hemispheres. They follow, for the most part, the sulci of the hemispheres, although connected across the gyri by numerous anastomoses, and they open above into the superior longitudinal sinus. The various veins show a tendency to increase in size from before backward, and while the anterior ones have a course almost at right angles to the superior longitudinal sinus, the more posterior ones are directed forward as well as upward and open obliquely into the sinus and in a direction contrary to the flow of the blood contained within it.

2. **The Middle Cerebral Vein.**—The middle cerebral vein (**v. cerebri media**), also termed the *superficial Sylvian vein*, lies superficially along the line of the Sylvian fissure and opens below into either the cavernous or the spheno-parietal sinus. It receives affluents from the surface of the brain on either side of the fissure and through these anastomoses with both the superior and inferior cerebral veins. One of these affluents which lies approximately along the line of the fissure of Rolando is usually of large size and communicates directly with one of the superior cerebral veins, the two forming what is known as the *great anastomotic vein of Trolard*, uniting the superior longitudinal sinus with the median cerebral vein.

3. **The Inferior Cerebral Veins.**—The inferior cerebral veins (**vv. cerebri inferiores**) are a number of small veins which occupy the inferior surfaces of the hemispheres. They are somewhat irregular in their arrangement, those of the frontal lobes anastomosing with the superior cerebrals and opening into the anterior portion of the superior longitudinal sinus, while those of the temporo-sphenoidal region anastomose with the middle cerebral and open into the spheno-parietal, cavernous and superior petrosal sinuses and into the basilar vein.

4. **The Great Cerebral Vein.**—The great cerebral vein (**v. cerebri magna**), also known as the *great vein of Galen*, is a short stem about 1 cm. in length which is formed beneath the splenium of the corpus callosum in the neighborhood of the pineal body, by the union of the two internal cerebral veins. It passes backward and upward, curving around the posterior extremity of the corpus callosum, and terminates (Fig. 756) by opening into the anterior end of the straight sinus.

Tributaries.—The great cerebral vein is formed by the union of the two (*a*) **internal cerebral veins** (**vv. cerebri internæ**), also known as the *small veins of Galen*. These are situated, one on either side of the median line, in the velum interpositum, which forms the roof of the third ventricle. Each is formed at the foramen of Monro by the union of three veins, the choroid vein, the vein of the septum lucidum, and the vein of the corpus striatum. The **choroid vein** (**v. chorioidea**) seems to be the direct continuation of the internal cerebral vein. It begins at the junction of the body and descending horn of the lateral ventricle, passes forward along the floor of the ventricle in the outer edge of the choroid plexus, and opens at the foramen of Monro into the internal cerebral vein of its side. The **vein of the septum lucidum** (**v. septi pellucidi**) passes backward along the outer (ventricular) surface of the septum lucidum, returning the blood from the head of the caudate nucleus and neighboring parts, and the **vein of the corpus striatum** (**v. terminalis**), which drains the lenticular nucleus and to a certain extent the caudate nucleus also, passes backward in the groove between the corpus striatum and the optic thalamus (stria terminalis).

(*b*) The **posterior vein of the corpus callosum** passes backward from about the middle of the superior surface of the corpus callosum and, bending around the splenium, empties into the great cerebral vein or into the internal cerebral vein near its termination. It receives blood from the corpus callosum and from the median surface of the hemisphere.

(*c*) The **basilar vein** (**v. basalis**) is a large paired vein which arises at the anterior perforated space by the junction of the deep Sylvian vein with the anterior vein of the corpus callosum. It passes backward over the optic tract of its side and then curves upward around the crus cerebri to reach the dorsal surface of the brain-stem, where it opens into either the great or the internal cerebral vein. Occasionally the terminal portion which bends upward around the

crus is lacking, the vein then emptying into the cavernous sinus. The **deep Sylvian vein**, which is its main stem of origin, begins in a number of vessels which ramify over the surface of the insula (island of Reil) and passes downward and forward at the bottom of the Sylvian fissure to become continuous with the basilar at the anterior perforated space. Occasionally it unites with the lower portion of the middle cerebral vein or opens with it into the spheno-parietal sinus. The **anterior vein of the corpus callosum** corresponds to the anterior cerebellar artery, sometimes termed the anterior central vein; it arises on the anterior part of the upper surface of the corpus callosum and bends downward around the genu to unite with the deep Sylvian vein at the anterior perforated space.

The basilar vein drains all the central part of the base of the brain, and, in addition to the two veins which are regarded as its stems of origin, it receives branches from the optic tract, the olfactory bulb, the anterior perforated space, the tuber cinereum, the corpora mammillaria, and the posterior perforated space, and it furthermore receives a vein from the superior vermis of the cerebellum. The veins of the anterior perforated space are from ten to fifteen in number and have their origin in the nuclei of the corpus striatum and in the internal capsule, while those of the posterior perforated space drain the optic thalami.

Practical Considerations.—The free communication of the thin-walled valveless cerebral veins with one another is one of the agents for the equalization of intracranial venous pressure. An anastomotic trunk unites the middle cerebral vein with the posterior cerebral, thus permitting the passage of venous blood by means of the anterior basilar vein into the sinuses about the foramen magnum. Relief from excessive intracranial blood-pressure may, in addition, be effected by the escape of blood from within the cranium (*a*) in the occipital region through the internal jugular and mastoid vein; (*b*) in the frontal region through the ophthalmic vein and the vein traversing the foramen ovale; (*c*) in the basal region through the petrosal sinuses and the posterior condyloid vein; and (*d*) at the vertex through the diploic veins and the venules penetrating the outer table of the cranium to join those of the scalp (Allen).

The avoidance of sudden depletion of the intracranial venous channels through the inspiratory emptying of the large extracranial veins is admirably provided for and the mechanism should be understood, as it has practical relation to many phenomena of cerebral anæmia and hyperæmia, to shock and syncope and concussion, to sinus thrombosis, and to many other intracranial conditions. The chief factors in equalizing the flow in the sinuses—and thus practically throughout the brain—may be briefly summarized as follows:

(*a*) The oblique entrance into the longitudinal sinus of its tributaries—the larger middle and posterior cerebral veins—pouring their blood into it against the stream; (*b*) the division of the sinus at the Torcular Herophili into two trunks diverging at right angles; (*c*) the course of the blood-current in the lateral sinus—first horizontal, with a convexity outward; then—in the first part of the sigmoid—vertical; then horizontal, with a convexity downward, and then a quick upward and outward turn, with narrowing of its calibre before entering the jugular fossa; (*d*) the widening of the upper part of this fossa—which is above the outlet of the sigmoid—and the narrowing of its exit (Macewen). Were it not for these and other subsidiary anatomical arrangements contributing to the same end, the effect of a deep inspiration on the cervical veins (page 863) would be so to aspirate the venous channels of the brain as to cause faintness or momentary unconsciousness.

The cerebral veins are so delicate that in operations upon the brain it is often better to arrest bleeding by gauze-pressure than to attempt to seize and tie separate vessels.

5. **The Cerebellar Veins.**—The cerebellar veins form a net-work over the surface of the cerebellum, the course of the larger stems being, for the most part, at right angles to that of the foliæ.

The **superior cerebellar veins** (vv. cerebelli superiores) open in part laterally into the lateral and superior petrosal sinuses, while others pass medially and unite to form a **superior median cerebellar vein**, which passes forward and downward along the superior vermis and opens either into the great cerebral vein or the terminal portion of the basilar vein.

The **inferior cerebellar veins** (**vv. cerebelli inferiores**), somewhat larger than the superior, pass in part forward and outward to open into the lateral or superior petrosal sinuses, and in part backward to unite with the occipital sinus.

The Ophthalmic Veins.

The ophthalmic veins take their origin from the contents of the orbit and pass from before backward, uniting to form two principal trunks, a large superior and a smaller inferior ophthalmic vein, which open at the sphenoidal fissure into the anterior extremity of the cavernous sinus. At the margin of the orbit both veins form important connections with the angular vein, and, since no valves occur in any of the branches of the ophthalmic veins, they form important emissaries connecting the cavernous sinus with the facial vein.

1. **The Superior Ophthalmic Vein.**—The superior ophthalmic vein (**v. ophthalmica superior**) (Fig. 757) is formed at the inner angle of the orbit by the fusion of usually two vessels which come from the supra-orbital and angular veins and pass respectively above and below the pulley of the superior oblique muscle of the eye and unite a short distance posterior to that structure. The anterior portion of the superior ophthalmic vein so formed is sometimes termed the *v. naso-frontalis*, and in its further course it is directed somewhat tortuously, at first obliquely backward and outward, passing across the optic nerve and beneath the superior rectus muscle, and then more directly backward to the sphenoidal fissure.

Tributaries.—The superior ophthalmic receives numerous tributaries from both the eyeball and the other contents of the orbit, most of the branches from the latter sources corresponding to branches of the ophthalmic artery. Thus it receives (*a*) the **anterior** and (*b*) the **posterior ethmoidal veins** (**vv. ethmoidales anterior et posterior**) which return blood from the sphenoidal sinus and the superior meatus and turbinate bone of the nose, communicating with the other veins of the nasal cavity and entering the orbit by the ethmoidal foramina; (*c*) the **lachrymal vein** (**v. lacrimalis**), a vein of considerable size arising in the lachrymal gland and accompanying the artery of the same name; and (*d*) **muscular veins** (**vv. musculares**) which return the blood from the levator palpebræ superioris, the superior and internal recti, and the superior oblique, the veins from the other muscles of the orbit usually opening into the inferior ophthalmic vein.

From the eyeball it receives (*e*) the two **superior venæ vorticosæ**. These veins return the blood from the choroid coat, the ciliary body, and the iris, and are four in number, each having its origin from a rich plexus which occupies one of the four quadrants of the choroid, the principal stems of the plexus radiating from all directions towards the central point of its quadrant. Here they unite to form a single trunk which pierces the sclera obliquely at about the equator of the eyeball, the veins from the two superior quadrants emptying into the superior ophthalmic, while the two from the inferior quadrants connect with the inferior ophthalmic. Occasionally five or six venæ vorticosæ exist, and they open sometimes into the muscular veins instead of directly into the ophthalmic stems. (*f*) The **anterior ciliary veins** (**vv. ciliares anteriores**) are very slender veins which leave the eyeball at the points where the recti muscles are inserted into the sclerotic; two or three veins are associated with each muscle-tendon and open into the muscular veins. (*g*) The **posterior ciliary veins** (**vv. ciliares posteriores**) accompany the posterior or short ciliary arteries. The territory supplied by the arteries is, however, drained by the venæ vorticosæ, and the posterior ciliary veins, which are very small, take their origin only from the posterior portion of the sclerotic and from the sheath of the optic nerve. (*h*) The **vena centralis retinæ** is a single stem which accompanies the corresponding artery through the centre of the optic nerve, and has its origin in branches which ramify over the surface of the retina. The vein leaves the optic nerve usually before the artery and opens either into the superior ophthalmic vein or, more frequently, directly into the cavernous sinus.

2. **The Inferior Ophthalmic Vein.**—The inferior ophthalmic vein (**v. ophthalmica inferior**) (Fig. 757) takes its origin from a net-work of small veins situated on the inner portion of the floor of the orbit near its border. This plexus communicates with the facial vein and is continued backward towards the fundus of the orbit, more frequently as a coarse net-work than as a definite stem. The vein, when it exists, or the net-work, anastomoses with branches of the superior ophthalmic.

Tributaries.—(*a*) **Muscular branches** from the inferior and external recti and the inferior oblique muscles and (*b*) the **inferior venæ vorticosæ** from the lower half of the eyeball. It opens posteriorly either directly into the cavernous sinus or else unites with the superior ophthalmic vein.

Anastomoses of the Ophthalmic Veins.—The ophthalmic veins are throughout destitute of valves and open posteriorly into the cavernous sinus, and, since they also communicate with peripheral veins, they may well be regarded as emissary channels through which the blood may flow either from the cavernous sinus to the peripheral veins or in the reverse direction, as may be determined by the relative pressure within and without the cranium. The principal connections which the veins make are (1) with the facial vein, which is itself practically devoid of valves, through their branches of origin; (2) with the veins of the nasal cavity through the ethmoidal branches; and (3) with the pterygoid plexus by means of a branch of the inferior ophthalmic which passes downward through the spheno-maxillary fissure.

Practical Considerations.—The communication between the superior ophthalmic vein—the largest channel in the adult between the vessels of the venous system of the head and face and the sinuses of the dura mater—and the facial vein, while adding to the danger of intracranial complications as a result of infectious disease situated upon the face (page 873), affords relief to intraocular tension in cases of pressure upon the cavernous sinus, as from an inflammatory exudate or an intra-orbital or intracranial growth. Such relief delays the appearance of "choked disc" (page 1471), due to the distension of the tributaries of the vein, especially the posterior ciliary veins and the vena centralis retinæ. In arterio-venous aneurism of the cavernous sinus and internal carotid artery—due to basal cranial fracture, a bullet- or stab-wound, or to idiopathic vascular degeneration—the ophthalmic veins are usually compressed and may transmit pulsation from the sinus to the dilated veins of the eyelids and of the frontal region. The conjunctivæ are congested. Exophthalmos (page 1439), bruit and thrill are not uncommonly present as a result of involvement of the intraorbital veins. Nervous symptoms—noise in the head, intracranial or frontal pain and paralyses—are rarely absent.

These symptoms may be simulated by those caused by traumatic aneurism of an orbital artery or by the direct pressure of an internal carotid aneurism on the ophthalmic vein as it empties into the sinus.

The External Jugular Vein.

The external jugular vein (**v. jugularis externa**) (Fig. 759), notwithstanding its usual connection with the subclavian, is closely related both in its development and topographical relations with the internal jugular, and may be most conveniently considered here. It is formed in the neighborhood of the angle of the mandible by the union of the temporo-maxillary and posterior auricular veins, and courses downward immediately below the platysma, crossing the sterno-cleido-mastoid muscle obliquely. In the lower part of the neck it pierces the superficial layer of the deep cervical fascia, sometimes above and sometimes below the posterior belly of the omo-hyoid, and opens into the subclavian vein near its junction with the internal jugular. A short distance below its origin it gives off a large branch which passes forward and downward to communicate with the facial vein.

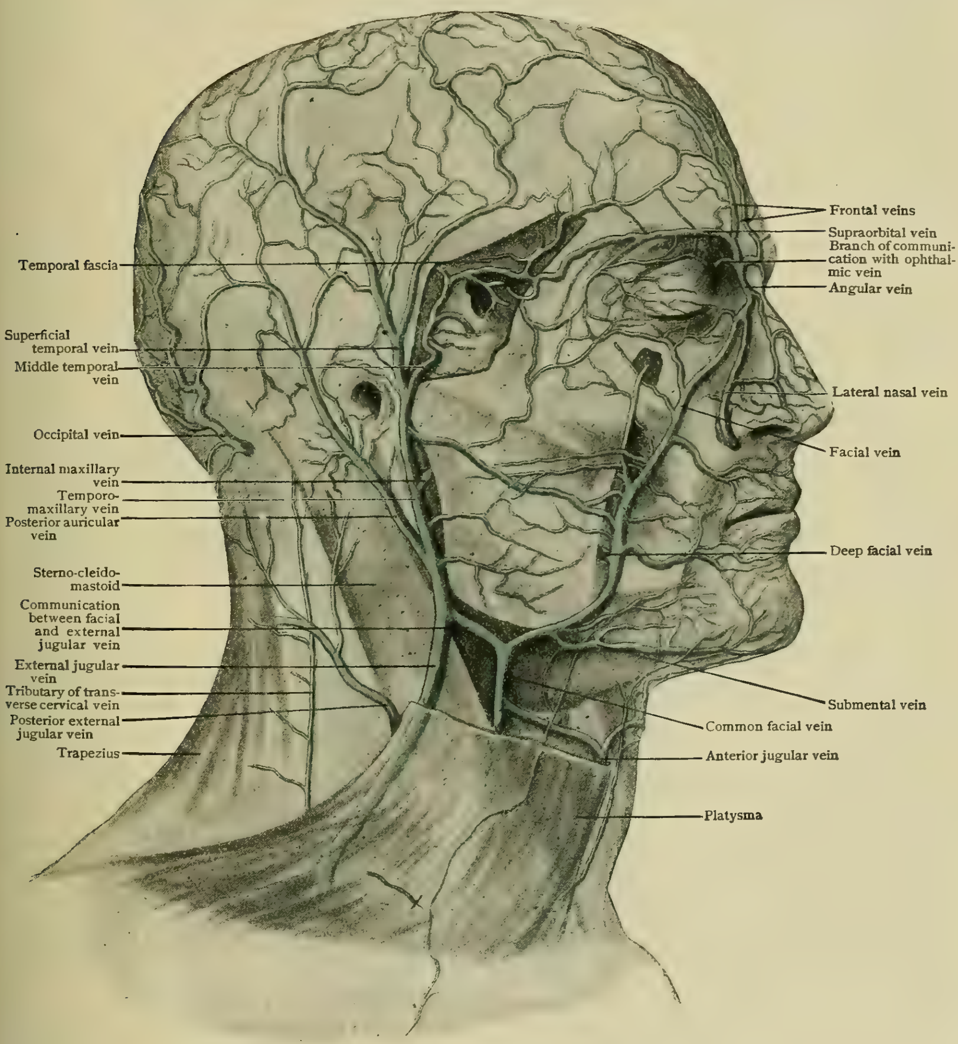
At its entrance into the subclavian it is provided with a pair of valves, and usually a second pair occurs at about the middle of the neck. A third pair is occasionally present in the interval between the other two, and all of them are insufficient. The superficial layer of the deep cervical fascia is intimately adherent to the walls of the vein at the point where the latter perforates it, and sometimes the fascia is especially thickened immediately below and to the inner side of the vein. This attachment of the fascia prevents any collapse of the walls of the lower part of the vein, if for any reason there is a deficiency in the amount of blood it contains, and predisposes, therefore, to the entrance of air in case the vein is severed.

Variations.—Considerable differences of opinion exist as to the definition of the external jugular vein. Some authors describe it as formed by the union of the posterior auricular and occipital veins, the communicating branch described above as occurring between it and the facial being then regarded as the main stem of the temporo-maxillary; others, again, regard it as formed by the union of the temporal and maxillary veins, the temporo-maxillary then constituting its upper portion.

The vein is subject to considerable variation in size, an inverse correlation existing between it and the anterior jugular. It may even be entirely wanting or, on the other hand, it may be double throughout a portion of its course. It occasionally divides below, one branch passing, as usual, to the subclavian, while the other, passing over the clavicular attachment of the sterno-cleido-mastoid, opens into either the anterior or the internal jugular.

In connection with the abundant variation shown in the size of the external jugular it is interesting to note that in the majority of mammals it is the most important vein of the neck, surpassing the internal jugular in size. It is, however, of later development than the latter, and its later importance is due largely to the union with it of the facial vein or of the linguo-facial trunk. In man, however, a new connection of the facial with the internal jugular occurs, whereby the importance of the external jugular becomes reduced, and its variation in size is largely dependent upon the extent to which the original direct connection of the facial with it is retained.

FIG. 759.



Superficial veins of head and neck; external jugular lies beneath platysma muscle, which has been partly removed.

Practical Considerations.—The line of the external jugular vein is from the angle of the jaw to the centre of the clavicle. Backward pressure made about an inch above the latter point will cause the vein to become visible throughout its length. For that reason it was at one time selected for phlebotomy in congestions or inflammations about the face and neck. The vein is in the superficial fascia and therefore courses over the sterno-mastoid muscle. In all operations on the side of the neck its size and its course should be borne in mind.

Tributaries.—The tributaries of the external jugular are (1) the *temporo-maxillary*, (2) the *posterior auricular*, (3) the *posterior external jugular*, (4) the *suprascapular*, and (5) the *anterior jugular vein*. It may also receive the occipital vein (page 859).

1. **The Temporo-Maxillary Vein.**—The temporo-maxillary vein (**v. facialis posterior**) (Fig. 753) is formed in the substance of the parotid gland by the union of the temporal and internal maxillary veins. It passes directly downward, and at about the angle of the jaw unites with the posterior auricular vein to form the external jugular.

The **temporal vein** accompanies the temporal artery and is formed just above the zygoma by the union of the superficial and middle temporal veins. The **superficial temporal vein** (**v. temporalis superficialis**) (Fig. 759) is formed by the union of an anterior and a posterior branch, which take their origin in a plexus covering the greater portion of the skull-cap and communicate anteriorly with branches of the frontal vein and posteriorly with the posterior auricular and occipital veins. The **middle temporal** (**v. temporalis media**) arises from a plexus which lies upon the outer surface of the temporal muscle, beneath the temporal fascia and above the zygoma. Branches of the plexus pierce the temporal fascia near the external angle of the eye and communicate with branches of the facial and lachrymal nerves, while other branches pass deeply into the substance of the temporal muscle and anastomose with the deep temporal veins. The middle temporal, from its origin in the plexus, passes backward parallel with the upper border of the zygoma, perforates the temporal fascia, and joins with the superficial temporal vein.

Tributaries.—The temporal vein receives the following tributaries. (*a*) The **anterior auricular veins** (**vv. auriculares anteriores**) are four or five small vessels which come from the anterior surface of the pinna. (*b*) The **posterior parotid veins** (**vv. parotideae posteriores**), small branches which drain the parotid gland, communicating with the anterior parotid branches of the facial. (*c*) The **articular veins** (**vv. articulares mandibulae**), several in number, arise in a rich plexus which surrounds the synovial membrane of the temporo-mandibular articulation. This plexus receives **tympanic branches** (**vv. tympanicae**), which accompany the tympanic artery through the Glaserian fissure, and communicates anteriorly with the pterygoid plexus. (*d*) The **transverse facial vein** (**v. transversa faciei**) which accompanies the artery of the same name.

The **internal maxillary vein** (**v. maxillaris interna**) (Fig. 760) appears sometimes as a distinct vessel accompanying the internal maxillary artery and receiving as tributaries veins corresponding to the arterial branches. In other cases it is represented by a plexus of veins, frequently exceedingly dense, occupying the pterygoid fossa and communicating anteriorly with the facial vein and posteriorly with the temporo-maxillary. This **pterygoid plexus** (**plexus pterygoideus**) (Fig. 760) is embedded in the adipose tissue which occupies the pterygoid fossa and consists of two portions, one situated upon the outer surface of the external pterygoid muscle and the other between the two pterygoids, this latter plexus being somewhat more extensive than the other, with which it is united by branches passing through, above, and beneath the external pterygoid muscle. It is also continued forward as a fine plexus surrounding the infra-orbital nerve, and that portion which rests upon the tuberosity of the maxilla is occasionally more or less distinct from the remainder, and has been termed the *plexus alveolaris*.

The pterygoid plexus communicates with the facial vein through the deep facial or anterior internal maxillary vein, with the pharyngeal plexus, and with the articular plexus of the temporo-mandibular articulation. It further receives the emissary veins from the cavernous plexus which traverse the foramen ovale, the foramen of Vesalius, and the foramen lacerum medium, and also a branch from the inferior ophthalmic vein which passes through the spheno-maxillary fissure.

Tributaries.—The tributaries of the internal maxillary vein or the pterygoid plexus may be described as follows.

(*a*) The **spheno-palatine vein** has its origin in the rich venous plexus which underlies the mucous membrane of the nasal cavity and with which the ethmoidal veins also communicate. It traverses the spheno-palatine foramen with the artery of the same name, and is joined by the *Vidian*, *pterygo-palatine*, and *superior palatine veins*, all small vessels whose origin is indicated

by their names. It then passes between the two heads of the external pterygoid muscle and opens into the pterygoid plexus or into the internal maxillary vein.

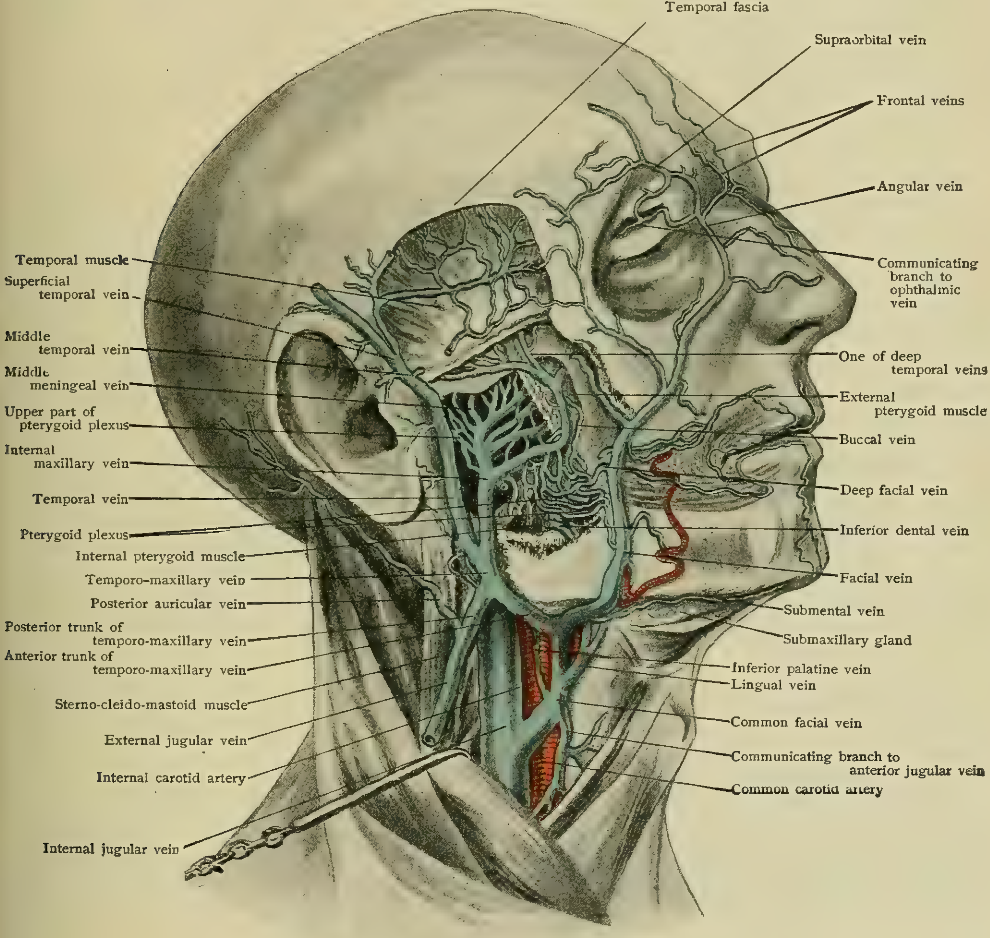
(*b*) The **superior dental veins** open into the infra-orbital and alveolar portions of the plexus.

(*c*) **Muscular veins** from the masseter, buccal, and pterygoid muscles.

(*d*) The **deep temporal veins** (**vv. temporales profundae**) descend from the substance of the temporal muscle, where they anastomose with the superficial temporals, between the muscle and the bone.

(*e*) The **middle meningeal veins** (**vv. meningeae mediae**) accompany the main stem and branches of the middle meningeal artery as venæ comites and return the blood from the dura mater lining the sides and vertex of the cranium. Lying in the substance of the dura mater, these veins resemble the sinuses of the dura in their structure, and they communicate with the blood-lakes of the dura, with the superior longitudinal, spheno-parietal and petro-squamosal sinuses, and with the superficial Sylvian vein. They open below into the deeper portion of the pterygoid plexus.

FIG. 760.



Veins of head; part of mandible and associated muscles have been removed to expose pterygoid plexus.

(*f*) The **inferior dental vein** follows the course of the inferior dental artery, opening above into the more superficial portion of the plexus.

2. **The Posterior Auricular Vein.**—The posterior auricular vein (**v. auricularis posterior**) arises from a plexus situated over the mastoid portion of the temporal bone and communicating with branches of the occipital and temporal veins. It descends

behind the pinna, occasionally receiving the mastoid emissary vein, and terminates near the angle of the jaw by uniting with the temporo-maxillary to form the external jugular.

3. **The Posterior External Jugular Vein.**—The posterior external jugular vein arises from the integument and muscles of the upper and back part of the neck, just below the occipital region, and descends obliquely behind the sterno-cleido-mastoid muscle to open into the external jugular just after it has crossed the muscle.

4. **The Suprascapular Vein.**—The suprascapular vein (**v. transversa scapulae**) is really a double vein, being represented by two vessels provided with valves which accompany the suprascapular artery as its venæ comites. They arise upon the upper part of the dorsal surface of the scapula, pass over the transverse ligament of that bone, and are continued inward, parallel with the clavicle and behind it, to open into the external jugular near its termination or else directly into the subclavian. Just before their termination the two venæ comites unite to a single stem.

The suprascapular vein is usually joined either at or near its termination by the *transverse cervical veins* which form the venæ comites of the transversalis colli artery. These veins may also open, however, directly into the subclavian.

5. **The Anterior Jugular Vein.**—The anterior jugular vein (**v. jugularis anterior**) (Fig. 753) arises beneath the chin, upon the mylo-hyoid muscle, by branches which come from the integument and superficial muscles of that region, communicating with the submental branches of the facial. The vein passes almost vertically down the neck resting upon the sterno-hyoid muscle a short distance lateral from the median line, until it meets the anterior (inner) border of the sterno-cleido-mastoid near its sternal attachment. There it makes an abrupt bend, passing almost horizontally outward beneath the muscle to open into the external jugular immediately above its termination.

The anterior jugular receives a communicating branch, occasionally of considerable size, from the facial subcutaneous veins, and tributaries from the median region of the neck also open into it; it may also receive small branches from the larynx and thyroid gland.

It contains no valves. At its origin it is superficial to the deep cervical fascia, but below the hyoid bone it is embedded in the superficial layer of that fascia, and below lies in the spatium suprasternale (space of Burns) formed by the splitting of the fascia into two lamellæ. In this space there occurs a transverse anastomosis between the two veins, forming what is termed the **arcus venosus juguli**, and into this a number of small branches from neighboring structures open. The horizontal portion of the vein eventually pierces the posterior layer of the space to reach the external jugular.

Variations.—The anterior jugular varies considerably in size, inversely to the external jugular. Occasionally the two veins of opposite sides unite throughout the vertical portion of their course to form a single stem, which passes down the median line of the neck and has consequently been termed the **v. mediana colli**.

The communicating branch from the facial vein, which passes downward along the anterior border of the sterno-cleido-mastoid, is sometimes quite large, functioning as the direct continuation of the facial, which may thus pour its blood mainly, if not entirely, into the anterior jugular. Below, while the anterior jugular usually opens into the external jugular, yet it sometimes opens directly into the subclavian, and occasionally it receives near its termination an *external thoracic vein*, which ascends from the region of the mammary gland over the clavicle, posterior to the attachment of the sterno-cleido-mastoid.

The Subclavian Vein.

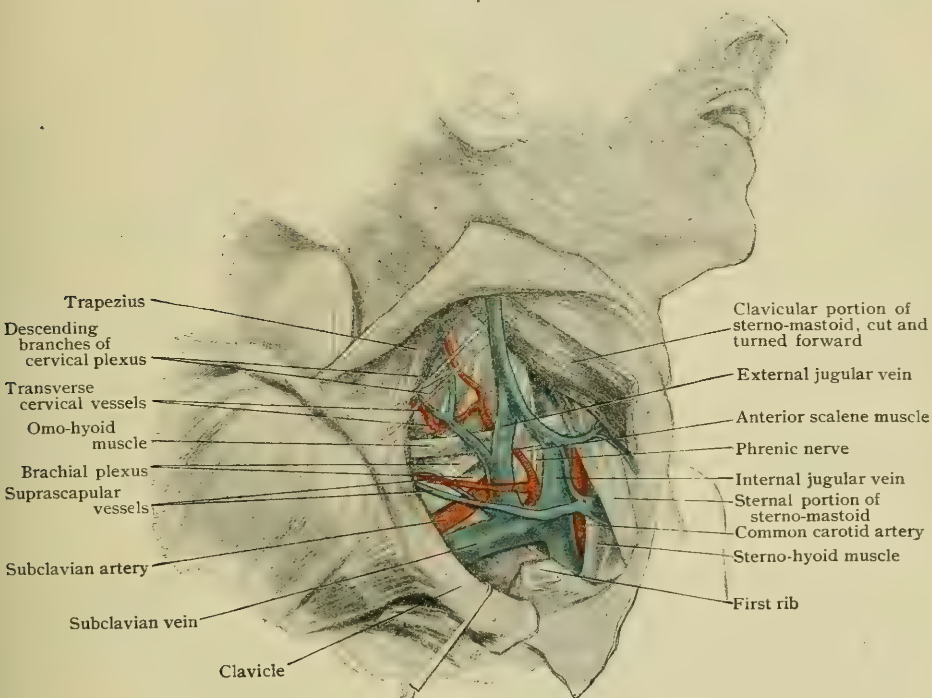
The subclavian vein (**v. subclavia**) (Fig. 753) is the terminal portion of the venous system of the upper extremity. It begins at the anterior border of the first rib, where it is directly continuous with the axillary vein, and passes almost horizontally inward, anterior to the scalenus anticus muscle and behind the clavicle, to the junction of that bone with the sternum, where it unites with the internal jugular to form the innominate vein. Its course is very similar to that of the subclavian artery, but it is more horizontal and somewhat anterior to the artery, from which it is separated by the scalenus anticus.

It is provided with a pair of valves at its junction with the internal jugular and with another pair at its junction with the axillary vein. In the first portion of its course it is in relation anteriorly with the subclavius muscle, and its anterior wall is united to

the fascia which encloses that muscle; near its termination it is united to the middle layer of the deep cervical fascia, behind which it lies. As a result of these connections the vein does not collapse when empty, and, furthermore, its lumen is enlarged by movements, such as those of inspiration or the raising of the arm, which affect the fascia.

With the exception of the external jugular and occasionally the anterior jugular, the subclavian vein receives, as a rule, no tributaries, the veins which correspond to the branches of the subclavian artery opening either into the innominate or the external jugular. Occasionally, however, it receives the suprascapular and the superior intercostal vein (page 896), and the acromial thoracic vein may open into it near its beginning.

FIG. 761.



Dissection of neck, showing relations of subclavian vein; clavicle has been disarticulated from sternum and drawn down.

Variations.—Occasionally the course of the subclavian vein has the form of a curve which rises above the level of the clavicle and may even bring the vein to lie above the artery. It may pass with the artery behind the scalenus anticus, the artery and vein may exchange places with reference to that muscle, or the vein may divide to form a ring encircling the muscle. Rarely it passes between the subclavius muscle and the clavicle.

Practical Considerations.—The subclavian vein occupies the acute inner angle between the clavicle and the first rib, and therefore—and on account of its slight resistance—in periosteal or osseous growths from those bones is especially likely to suffer compression. The interposed subclavius muscle usually protects it, as it does the artery and the brachial plexus, from injury in case of fracture (page 259). The vein barely rises above the clavicle, and therefore usually escapes in stab-wounds involving the supraclavicular fossa, while the artery which arches an inch to an inch and a half above that line suffers much oftener.

The connection of the anterior wall of the vein with the fascia of the subclavius muscle, causing an increase in its calibre during forced inspiration or an elevation of the arm (*vide supra*), should be remembered in case of wound of this vessel during

operation, as elevation of the clavicle may then be followed by the entrance of air into the vein (Henle). Obstruction of the subclavian at the point of junction with the internal jugular results in compression of the orifice of the thoracic duct.

THE VEINS OF THE UPPER EXTREMITY.

Instead of following distally the various branches which return the blood from the upper limb it will be more convenient to begin with the peripheral branches and trace the vessels proximally towards the subclavian.

The veins of the upper extremity may be divided into a *superficial* and a *deep* set. The latter follow in general the course of the arteries, of which they are, as a rule, the venæ comites. They anastomose frequently with the superficial veins and are more richly supplied with valves than are the latter.

THE DEEP VEINS.

The Deep Veins of the Hand.

The deep veins of the hand are all relatively small and are of less importance than the superficial ones in returning the blood. Each of the palmar arterial arches is accompanied by venæ comites, and into those of the superficial arch (**arcus volaris venosus superficialis**) the superficial digital veins (**vv. digitales volares communes**) open, while those of the deep arch (**arcus volaris venosus profundus**) receive the veins (**vv. metacarpeae volares**) which accompany the aa. princeps pollicis, radialis indicis, and interossei palmares.

Upon the dorsum of the hand even more than on its volar surface the chief part is played by the superficial veins. Three or four pairs of **dorsal interosseous veins** occur, however, accompanying the corresponding arteries and opening eventually partly into the radial veins and partly, through the veins corresponding to the posterior carpal net-work, into the superficial veins of the dorsum of the wrist (**rete venosum dorsale manus**). As in the case of the arteries, the deep veins of the dorsal and volar surfaces of the hand are connected by perforating veins, and both make numerous connections with the superficial veins.

The Deep Veins of the Forearm.

The deep veins of the forearm are the venæ comites which accompany the radial and ulnar arteries and their branches. The **radial veins** (**vv. radiales**) are the upward continuation of the veins of the deep palmar arch and are relatively slender. The **ulnar veins** (**vv. ulnares**) are larger and are formed by the union of the ulnar ends of the venæ comites of both the superficial and deep palmar arches. Usually they have a large communication from the superficial veins of the dorsum of the hand, and receive near the elbow the veins which accompany the interosseous artery and its branches, and also a strong communicating branch, the **deep median vein,** from the superficial median (page 890). Both the ulnar and radial veins are well supplied with valves, and they unite at the elbow to form the brachial veins.

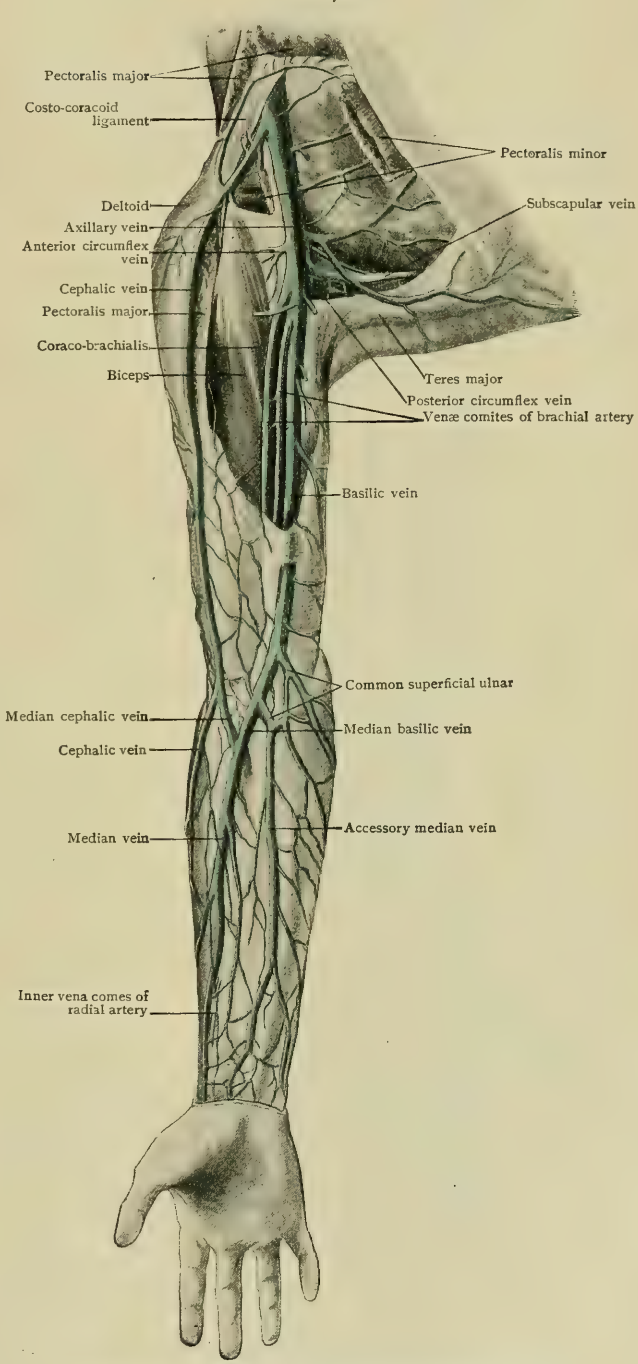
The Brachial Veins.

The brachial veins (**vv. brachiales**) (Fig. 762) are the companion veins of the brachial artery and receive tributaries corresponding to the branches of the artery. They are formed at about the elbow-joint by the union of the radial and ulnar veins, and extend upward, one on either side of the brachial artery, to the lower border of the pectoralis major muscle, at about which level they unite to form a single trunk, termed the axillary vein.

As is usual with venæ comites, the two brachial veins are united by numerous anastomoses and occasionally unite through portions of their course, especially above, to form a single trunk. At the elbow one of the veins frequently lies in front of the artery and sometimes the two veins pursue a spiral course around it. In addition to the tributaries which accompany the branches of the brachial artery, the brachial veins, or rather the inner one of the two, receive near their termination the basilic vein (page 890).

THE AXILLARY VEIN.

FIG. 762.



Superficial veins of anterior surface of right forearm and axillary vein and its tributaries.

The axillary vein (v. axillaris) (Fig. 762) is formed by the union of the two brachial veins, usually at about the lower border of the pectoralis major. It lies along the inner side of the axillary artery, and at the lower border of the first rib passes directly into the subclavian vein. In the lower part of its course it is separated from the artery by the ulnar nerve and the inner head of the median; above, it is more nearly in contact with it.

The axillary vein possesses a pair of valves, usually situated at the level of the lower border of the subscapularis muscle. Its walls are intimately connected with the fascia of the axillary space, so that, as in the case of the subclavian, its lumen remains patent even when empty of blood, and consequently air may possibly enter in cases where the vein is wounded.

Tributaries.—These correspond in general with the branches of the artery, except that the axillary vein receives the cephalic, which is unrepresented by an artery, and, furthermore, the acromial thoracic, which corresponds to the artery of the same name, instead of opening into the axillary, connects with the cephalic. Of especial importance among the tributaries is the **long thoracic vein** (v. thoracalis lateralis) which brings to the axillary the blood from the lateral walls of the thorax. Its branches of origin are the venæ comites of the branches of the thoracic arteries, and they return the blood from the

pectoral and serratus magnus muscles and in part from the intercostals. They are abundantly supplied with valves, and unite to a single stem which presents variations in its connections with the axillary vein similar to those described for the corresponding artery. By means of the **costo-axillary veins** (vv. costo-axillares), which pass from the middle portions of the upper six or seven intercostal spaces, it forms anastomoses with the intercostal veins which open into the azygos system.

These costo-axillary veins open either directly into the long thoracic or into the **thoraco-epigastric vein** (v. thoraco-epigastrica), a more or less definite stem which extends upward along the lateral walls of the thorax, subcutaneously, to open into the long thoracic near its termination. It receives numerous tributaries from the rich **subcutaneous venous net-work** which occurs upon the anterior and lateral walls of the thorax (vv. cutaneae pectoris), and communicates directly below with epigastric branches from the femoral vein, thus forming an important communication between the superior and inferior caval systems. It also receives the veins coming from the region of the mammary gland, where the pectoral cutaneous veins form a net-work surrounding the nipple, the **plexus venosus mammillæ.** The deeper veins of the gland open in part directly into the long thoracic, whence this has been termed the **external mammary vein,** and partly into the internal mammary by branches which accompany the perforating branches of the internal mammary artery (page 860).

Practical Considerations.—When the axillary vein is formed by the junction of the two brachial veins with the basilic vein, the union occurs usually at the inferior border of the subscapularis muscle. The vein is then somewhat shorter than the artery. Occasionally the coalescence of these tributaries does not take place until a level just beneath the lower border of the clavicle has been reached. When this is the case, operations in the axilla will involve the ligation of many communicating transverse veins crossing the artery to join the venæ comites lying upon either side of it.

Phlebitis of the veins of the upper extremity is but seldom transmitted to the axillary vein, rarely to the subclavian, and never to the internal jugular or innominate (Allen). This immunity is supposed to be due to disproportionately greater size of a main venous trunk as compared with its tributaries; any of the radicles of the veins of the hand, forearm, and arm—whose calibres are nearly equal—readily transmitting infection. Phlebitis of the axillary vein may, through the costo-axillary branches of the long thoracic vein, extend to within the thorax and result in a septic pleurisy.

Accidental wounds of the axillary vein—especially of its upper portion—are dangerous on account of its size, its nearness to the thorax—so that it markedly shows the respiratory wave—and its attachment to the costo-coracoid membrane, preventing its collapse, favoring hemorrhage, or, when it is empty, permitting the entrance of air. It lies within and a little below the artery, which it overlaps, particularly towards its upper and lower portions, and when it is distended during expiration. As it is straighter than the artery, the curve of the latter carries it a little away from the vein at the middle portion. Abduction of the arm brings the vein to a higher level and often almost in front of the artery so as partly to hide it. It will therefore be found with this relationship in many operations upon the axilla, and it is on account of it—*i.e.*, its more superficial position—and of its larger size that the vein is more frequently wounded than is the artery. On the other hand, the axillary artery is oftener ruptured, as in the manipulations for the reduction of old luxations of the shoulder, probably, as such luxations are more frequent in old persons, on account of the greater loss of elasticity of its thicker walls, and possibly on account of greater traction upon it by reason of its deeper and more external position (page 769).

The close relation of the vein to the deep chain of axillary glands makes it the chief source of danger in operations for the removal of the breast and cleaning out the axilla in cases of mammary cancer, especially if the axillary nodes are already notably involved. It is well, therefore, to expose the vein at an early stage of the operation. If the walls have been invaded by the disease, or if extirpation of the cancerous mass is impossible without resection of the vein, the latter operation may

be performed. The resulting swelling and œdema of the upper limb are minimized by the consecutive enlargement of the cephalic vein. Such swelling and œdema are common symptoms of pressure upon the axillary vein by cancerous lymph-nodes in the later stages of mammary cancer (page 770). Suture of the wall of the vein in cases of accidental and of operative wound has been successfully performed.

THE SUPERFICIAL VEINS.

The Superficial Veins of the Hand.

The veins upon the **dorsal surface** (Fig. 763) form the principal superficial channels for the return of blood from the hand. They begin in a plexus upon the dorsum of the first phalanges, surrounding the nail, and are continued over the succeeding phalanges as a coarser plexus in which longitudinal trunks (**vv. digitales dorsales propriae**) can be more or less distinctly perceived. At about the middle of the dorsum of the proximal phalanges transverse arches (**arcus venosi digitales**), one for each digit, connect the various dorsal digital veins ; each arch is concave proximally, and at either end unites with the extremities of the neighboring arches to form four **dorsal metacarpal veins** (**vv. metacarpeae dorsales**) which pass upward along the lines of the intermetacarpal spaces. Just before joining with its neighbors each digital arch receives **intercapitular veins** (**vv. intercapitulares**) which ascend in the web of the fingers from the volar surface and assist in the passage of the blood of the superficial volar veins into those of the dorsal surface.

Fig. 763.

Superficial veins of right hand and forearm ; posterior surface.

The four dorsal metacarpal veins are abundantly connected by anastomosing branches which pass obliquely from one vein to the other, a net-work (**rete venosum dorsale manus**) with elongated meshes being thus formed. The veins of the first and fourth intermetacarpal spaces, as a rule, however, retain a greater amount of individuality than the other two, and have consequently received special names, that of the first interspace being sometimes termed the **vena cephalica pollicis,** while that of the fourth interspace is the **vena salvatella.** The dorsal net-work is drained by two veins which pass up the forearm, the cephalic and basilic veins.

The superficial veins of the **volar surface** of the hand are small and for the most part open into the dorsal veins. They arise as a plexus in the balls of the fingers and pass along the volar surfaces of the digits as a plexus in which longitudinal trunks (**vv. digitales volares propriae**) can be distinguished. From the plexus of each finger branches wind around the sides of the digits to open into the dorsal digital veins, and at the roots of the fingers important connections in a similar direction are made by the intercapitular veins (see above).

The superficial veins of the **palm of the hand** are situated superficially to the palmar aponeurosis. They are for the most part small, and form a net-work which is open over the central part of the palm, but much closer over the thenar and hypothenar eminences. These lateral portions communicate with the dorsal net-work as well as the net-work of the anterior surface of the forearm, into which the central portion opens.

The Basilic Vein.

The basilic vein (**v. basilica**) (Fig. 762) takes its origin from the ulnar side of the dorsal net-work of the hand, and is sometimes described as the direct continuation of the dorsal metacarpal vein of the fourth interspace. It passes obliquely upward and inward, winding around the border of the hand towards the anterior surface of the forearm, up which it ascends. Beyond the bend of the elbow it continues its way upward along the inner border of the biceps muscle as far as the upper third of the brachium, at which level it pierces the fascia of the arm, and after a usually short subfascial course terminates by opening into the internal brachial vein.

The basilic is the largest of all the superficial veins of the arm, and is provided with from ten to fifteen pairs of valves. It receives tributaries from the superficial plexus of the thenar eminence and from the anterior and posterior surfaces of the forearm. Near the elbow it receives from the cephalic vein the median vein, the connecting stem being termed the *median basilic vein*, and it also communicates with the cephalic higher up by branches which pass across the biceps muscle, and with the brachial veins by small branches which pierce the brachial fascia.

Variations.—The basilic is little subject to variation except in regard to its termination, which is frequently in the axillary and sometimes in the subclavian ; in both these cases the subfascial portion of its course is considerably longer than usual. Occasionally it is accompanied throughout its course by an accessory basilic.

The portion of the vein extending from its origin to the bend of the elbow is frequently spoken of as the *superficial ulnar vein*, the term basilic being limited to the brachial portion of the vein as described above.

The Cephalic Vein.

The cephalic vein (**v. cephalica**) (Fig. 762) takes its origin from the radial portion of the dorsal net-work of the hand, and especially from the dorsal metacarpal vein of the first interspace. It passes upward, inclining forward over the surface of the brachio-radialis muscle, and so reaches the anterior surface of the forearm. Arrived at the bend of the elbow, it ascends along the groove which marks the outer border of the biceps muscle and then in the groove between the deltoid and the pectoralis major, and at the upper border of the latter muscle it passes between it and the clavicle, perforates the costo-coracoid membrane, and, crossing in front of the axillary artery, empties into the axillary vein.

It is provided with from twelve to fifteen pairs of valves, of which from four to seven occur in its antibrachial portion, seven in its brachial portion, and one at its union with the axillary.

Tributaries.—The cephalic vein receives numerous branches from the superficial net-work of the posterior surface of the forearm and, indeed, plays a much more important part in the drainage of this region than does the antibrachial portion of the basilic. Quite frequently it is accompanied in its course up the forearm by an **accessory cephalic vein** (**v. cephalica accessoria**), which arises in the posterior superficial net-work and opens into the main cephalic vein at the bend of the elbow. It also receives branches from the superficial net-work of the anterior surface of the forearm and, a short distance below the bend of the elbow, gives off a strong branch, the **median vein** (**v. mediana cubiti**), which passes obliquely upward and inward to open into the basilic, giving off in its course a communicating branch to one or other of the deep veins of the forearm.

In its brachial portion it is connected with the basilic by branches which pass across the biceps muscle, and just before opening into the axillary it receives the **acromial thoracic vein** (**v. thoracoacromialis**), which corresponds to the artery of the same name.

Variations.—Unlike the basilic, the cephalic vein frequently presents variations which affect principally its brachial portion. One of the most important of these is the complete absence of this portion of the vein, the antibrachial portion emptying its blood into the basilic by means of the median vein. In other cases it is only the uppermost part of the brachial portion that is lacking, the lower part in such cases either making connection with the brachial veins or else conveying its blood downward to the median vein, by which it passes to the basilic.

Another interesting anomaly consists in the occurrence of a branch which is given off just as the vein dips downward to pierce the costo-coracoid membrane. It is termed the *jugulo-cephalic vein*, and passes up over the clavicle to open above into the external jugular near its communication with the subclavian.

These variations find an explanation in the changes undergone by the superficial veins of the arm during their development, both the absence of the brachial portion of the vein and the occurrence of a jugulo-cephalic being the persistence of conditions normally passed through in development. It would seem that three, or perhaps better four, stages are to be recognized in the development of the superficial veins of the arm. In the first stage the basilic vein forms the only great superficial trunk, extending up the inner side of the arm from the wrist to the axilla and opening into the axillary vein above. Later, however, this condition is modified by the development of the antibrachial portion of the cephalic, which increases in size at the expense of the antibrachial portion of the basilic until it becomes the most important vein of the forearm. At the bend of the elbow this vein receives a short transverse branch formed by the union of an ascending and descending limb, and then bends obliquely inward to join the brachial portion of the basilic. Higher up in the groove between the pectoralis major and deltoid muscles is a small deltoid vein, which is unconnected with the veins already described. Such a stage as this gives a clue to the variations in which the brachial portion of the cephalic is either absent or only partially developed. The ascending limb of the transverse branch of the elbow, and this branch itself, together represent what will later be the lower part of the brachial portion of the cephalic, while the deltoid vein represents its upper part ; the descending limb of the transverse branch represents the accessory cephalic vein, and the oblique portion of the antibrachial cephalic, between the transverse branch and the basilic, represents the median vein. Indeed, relics of this condition are to be seen even in the normal arrangement, for while the antibrachial portion of the cephalic usually exceeds in size the corresponding portion of the basilic, the conditions are reversed in the brachial portions of the two veins, the antibrachial portion of the cephalic and the brachial portion of the basilic (connected by the median) forming the main channel for the return of blood from the superficial portions of the arm.

A third stage is brought about by the completion of the cephalic vein by the union of the ascending limb of the transverse branch with the deltoid, the vein so formed being continued up over the clavicle to open into the external jugular ; and, finally, the fourth or adult stage is produced from this by the degeneration of that portion of the cephalic which corresponds to what is termed the jugulo-cephalic.

The antibrachial portion of the cephalic is frequently termed the *superficial radial vein*, the accessory cephalic being then the *accessory superficial radial.* Furthermore, it is to be noted that quite frequently one or more strong longitudinal stems are developed in the superficial network of the anterior surface of the forearm, and to one of these the term **median vein** has been applied. This condition has generally been accepted by the English and French anatomists as typical, and their description of the origin of the basilic and cephalic veins is as follows. The median vein when it reaches the bend of the elbow divides into two divergent stems (Fig. 764) which are termed the **median basilic** and **median cephalic veins.** The median basilic, which corresponds with what has been termed above the median vein, unites with the superficial ulnar to form the basilic vein, while the median cephalic, which represents the fœtal transverse branch of the elbow, similarly unites with the superficial radial to form the cephalic. Such an arrangement is undoubtedly of frequent occurrence ; but since the median vein, as understood in such a description, is so variable and so manifestly a secondary formation, and since the arrangement taken above as typical is not only also of frequent occurrence, but furthermore follows more closely the embryonic relations of the various vessels, it has been given the preference.

Practical Considerations.—The Veins of the Upper Extremity.

The Deep Veins.—The venæ comites of the radial artery have been said, when distended, to alter, by pressure, the character of the pulse. The numerous short anastomotic branches which unite the venæ comites of the brachial artery cross in front of that vessel and may have to be tied as a preliminary to ligation of the artery.

The Superficial Veins.—*The Hand.*—The veins of the dorsal surface are subcutaneous, prominent, and, in order that the circulation may not be interrupted during prehension, are much larger than those of the palmar surface. Like the other superficial veins of the upper extremity, they are scantily supplied with valves and are therefore easily distended by the effects of gravity or by any constriction of the limb above.

The Forearm.—The large size of the superficial veins in the forearm, their subcutaneous position, the small number of valves they contain, and the fact that most

of the venous blood of the limb is returned by them, make circular constriction of the arm or forearm—as in cases of poorly applied splints—especially dangerous. Swelling and œdema distal to the constriction are sure to result speedily and, if the pressure is continued, to be followed by ulceration or gangrene.

On the extensor surface of the forearm the superficial veins are less conspicuous than on the flexor, and between the olecranon and the level of the pronator teres insertion are almost completely lacking. This is the surface most exposed to traumatism, and along it main arteries and nerve-trunks are also absent.

The Elbow.—The vein given off by the median vein when it reaches the bend of the elbow, and known by the English and French anatomists (*vide supra*) as the median basilic, is of the greatest practical importance among the veins at the bend of the elbow. The M-like figure made by the superficial ulnar and superficial radial in uniting respectively with the median basilic and median cephalic to form the basilic and cephalic veins is by no means constant, but is present in only from one-half to two-thirds of all cases (Treves). Even, however, if the basilic and cephalic veins do not originate in this way, the median vein (if from the cephalic), the median basilic (if from the median), will be found beginning a short distance below the elbow, to the outer side of the biceps tendons, and crossing the tendon, the brachial artery, the brachial veins, and the median nerve, from all of which it is separated by the bicipital aponeurosis, the inner of the two lower biceps tendons of the old anatomists. The vein may, however, run either more transversely or more vertically and so have different relations to the artery and nerve; it is usually the largest of the anticubital veins, but may be smaller than the median cephalic, which is commonly the second in size, followed by the median, ulnar, and radial, in the order mentioned.

FIG. 764.

Superficial dissection of region of elbow, showing relation of veins and nerves.

For reasons explained above, abnormalities and even absence of the cephalic and radial veins are more frequent than those of the basilic.

For this reason, and on account of its large size, the greater quantity of blood it carries—as it is above the entrance of the deep median vein, and thus receives blood from the deep veins of the forearm—its superficial position, its prominence, and its relative fixation to the bicipital fascia by cellular tissue, the median basilic is the vein selected for either intravenous transfusion or phlebotomy. In opening the vein, certain dangers are to be avoided: (1) Wound of the brachial artery, if it results in a direct communication between the vein and artery, will cause an aneurismal varix; if it results in the formation of an intervening sac in the perivascular connective tissue, through which the blood from the artery flows before entering the vein, it will cause a varicose aneurism. (2) A septic wound may cause a lymphangitis from infection of the lymph-vessels accompanying the vein, and may result in axilary abscess. (3) Unnecessary damage to the filaments of the internal cuta-

neous nerve (lying in front of the vein) may give rise to chronic traumatic neuritis (Tillaux), while injury of the cutaneous branches of the musculo-cutaneous nerve (in closer relation to the median cephalic vein), or entanglement of those branches in the cicatrix, may, by reflex irritation acting through the motor fibres, cause tonic spasm of the biceps and brachialis anticus, "bent arm" (Hilton).

The Arm.—The cephalic vein and its anomalies should be studied in relation to ligation of the axillary artery (*q.v.*), the first portion of which it crosses (separated from it by the clavi-pectoral fascia), on its way to reach the axillary vein.

It may be remembered that the basilic vein pierces the brachial aponeurosis a little below the middle of the arm and ceases to be superficial.

THE AZYGOS SYSTEM.

The principal trunks of the azygos system of veins are persistent portions of the embryonic cardinal veins which drained the thoracic and abdominal walls, as well as the paired viscera of the abdomen, and united above with the jugular trunks to form the Cuvierian ducts (page 926). On the development of the inferior vena cava their importance diminished greatly, and in the adult they serve principally to collect the blood from the intercostal spaces. The reduction of the lower part of the left jugular vein (page 927) brought about further modifications of the left cardinal, its original connection with the left jugular being dissolved and a new one formed with the right cardinal. This latter vein forms what is termed the azygos vein of the adult, while what persists of the left one is known as the hemiazygos and accessory hemiazygos.

The Azygos Vein.

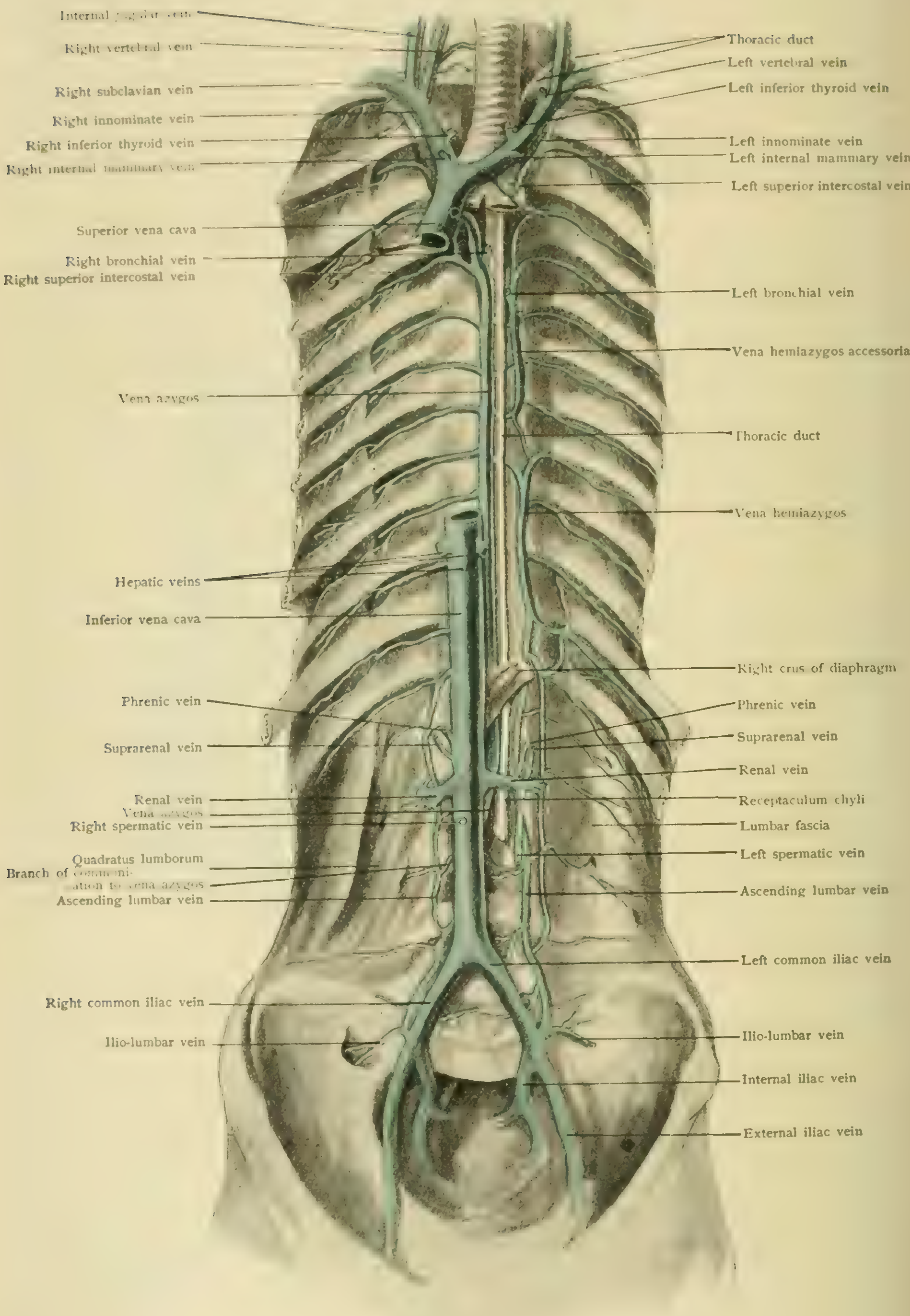
The azygos vein (**v. azygos**) (Fig. 765), sometimes called the *azygos major*, begins immediately below the diaphragm, where it is directly continuous with the right ascending lumbar vein, formed by the anastomosis of branches of the lumbar veins and connecting below with the ilio-lumbar or common iliac. The azygos vein passes upward into the thoracic cavity, traversing the diaphragm either by the cleft between the medial and intermediate portions of the right crus or else by the aortic opening. It then continues its way upward in the posterior mediastinum, resting upon the anterior surfaces of the bodies of the thoracic vertebræ a little to the right of the middle line, passing over the right intercostal arteries and having the thoracic aorta and the thoracic duct immediately to the left of it. When it reaches the level of the fourth vertebra it bends forward and somewhat to the right, and, curving over the right bronchus and the right pulmonary artery, it descends slightly to open into the posterior surface of the superior vena cava, just above the level at which that vessel becomes invested by the pericardium. The terminal portion of the vein from the fourth vertebra onward is sometimes termed the **azygos arch.**

The azygos vein in a considerable proportion (22 per cent., Gruber) of cases is entirely destitute of valves, and when present they rarely exceed four in number, are, apparently, never exactly paired, and are usually insufficient. They occur more frequently in the arch than in the vertical portion of the vein.

Tributaries.—The azygos vein at its origin has usually some small connections with the vena cava inferior, but its principal tributaries are the right intercostal veins. In addition it receives branches from the œsophagus (**vv. oesophageae**), from the areolar tissue and lymph-nodes of the posterior mediastinum and from a plexus which surrounds the thoracic aorta, from the posterior surface of the pericardium, and from the substance of the right lung, these last **bronchial veins** (**vv. bronchiales posteriores**) issuing from the hilum of the lung and opening into the azygos at the beginning of its arch. They anastomose with the pulmonary veins both along the course of the smaller bronchi and also outside the lung, and they receive some smaller bronchial veins (**vv. bronchiales anteriores**) situated upon the anterior surface of the bronchi. The azygos vein furthermore receives the hemiazygos vein ; this and the intercostal veins will be described below.

Variations.—Since the cardinal veins, from which the azygos and hemiazygos are formed, are primarily symmetrical, it may happen, just as was the case with the aortic arches, that it is the left one that is more fully retained and therefore becomes the azygos vein, the right becoming

FIG. 765.



Portion of posterior body-wall, showing azygos veins, superior and inferior vena cava, and their tributaries.

the hemiazygos. Occasionally, instead of opening into the superior vena cava, the azygos terminates in the right subclavian, the right innominate vein, or even opens directly into the right auricle. A further anomaly is sometimes presented by the azygos, in its upper part, being situated at the bottom of a deep groove upon the surface of the right lung, which thus comes to have an accessory lobe known as the azygos lobe or lobule.

Practical Considerations.—The azygos veins are the connecting links between the cardinal and the inferior caval systems. In cases of obstruction of the inferior cava they are able to carry on the collateral circulation very effectively, through their communication with the common iliac, renal, lumbar, and ilio-lumbar veins. Growths in the posterior mediastinum, enlarged bronchial glands, or aortic aneurisms may so compress these veins as to cause œdema of the chest wall by interference with the intercostal veins which empty into them.

The Hemiazygos Vein.

The hemiazygos vein (**v. hemiazygos**) (Fig. 765), also called the *azygos minor inferior*, is the counterpart, on the left side of the body, of the lower part of the azygos. It arises just below the diaphragm as the continuation upward of the left ascending lumbar vein (page 901), also receiving usually a communicating branch from the left renal vein. It passes upward into the thorax between the medial and intermediate portions of the left crus of the diaphragm, and then ascends upon the left side of the bodies of the lower thoracic vertebræ, passing in front of the lower left intercostal arteries and having the thoracic aorta to its right. At about the level of the eighth or ninth vertebra it bends towards the right and, passing behind the aorta and the œsophagus, opens into the azygos vein.

In its course it receives the lower five or four left intercostal veins, which constitute its principal tributaries, and in some cases it also receives the accessory hemiazygos vein. It also receives some branches from the œsophagus and from the posterior mediastinum.

The Accessory Hemiazygos Vein.

The accessory hemiazygos vein (**v. hemiazygos accessoria**) (Fig. 765), also called the *azygos minor superior*, is a descending stem which lies upon the left side of the bodies of the upper thoracic vertebræ and receives the upper left intercostal veins. It begins above at about the second intercostal space by the union of a small vein, which connects it with the left innominate, with the left superior intercostal. When it has reached the level of the seventh or eighth thoracic vertebra it bends to the right and, passing beneath the aorta and the œsophagus, opens into the azygos vein. Quite frequently it opens below into the hemiazygos just as that vein bends towards the right, and even when it has an independent connection with the azygos it may be connected with the hemiazygos by an anastomotic branch.

It receives the upper seven or eight left intercostal veins and in addition the left posterior bronchial vein.

Variations.—The hemiazygos and accessory hemiazygos veins together represent the left cardinal vein of the embryo which primarily opened into the left Cuvierian duct. With the disappearance of the lower part of the left jugular vein the relations of the left cardinal change, the vein making a connection across the middle line with the right cardinal (the azygos). Indications of the original condition are occasionally seen in a fibrous cord which connects the left superior intercostal vein, which is strictly a portion of the accessory hemiazygos, with the oblique vein of the left auricle (page 856).

As already pointed out in speaking of variations of the azygos, cases have been observed in which the hemiazygos and accessory hemiazygos occur upon the right side of the body, being formed from the right cardinal, while the left cardinal gives rise to the azygos. And more rarely the two veins have been observed fused to form a single trunk lying upon the anterior surface of the thoracic vertebræ and receiving all the intercostal arteries.

A considerable amount of variation exists in the number of intercostal veins received by the hemiazygos and the accessory hemiazygos respectively. Usually they divide between them the intercostals, since they either unite or cross the median line to the azygos over successive vertebræ. The hemiazygos has been observed to cross the vertebral column anywhere from the sixth to the eleventh vertebra, and the accessory may descend as far as the tenth or may cross at the third. In cases where it makes its crossing high up a number of intercostal spaces may inter-

venæ between it and the hemiazygos, and the veins of these then open directly into the azygos, passing, each independently, across the vertebral column beneath the aorta and œsophagus.

Absence of the accessory hemiazygos has been observed, the upper six or eight intercostal veins uniting to form a common ascending trunk which opens into the left innominate. In all probability, however, this common ascending stem is properly to be regarded as the accessory hemiazygos, whose normal connection with the innominate has increased in size while its connection with the azygos or hemiazygos has either degenerated or failed to form.

The Intercostal Veins.

The intercostal veins (vv. intercostales) (Fig. 765), sometimes designated as *posterior intercostal* as distinguished from the anterior intercostal tributaries of the internal mammary vein, accompany the intercostal arteries and are twelve in number on each side, one occurring in each intercostal space and one, sometimes termed the **subcostal vein,** running along the lower border of each twelfth rib. They lie along the upper border of the spaces to which they belong, in a groove on the lower border of the rib, and are above the corresponding arteries. The upper nine or ten veins open anteriorly into the internal mammary or musculo-phrenic veins, but the lower three or two, which are somewhat larger than the rest, have no anterior communication and receive tributaries from the abdominal muscles and the diaphragm. In the middle portion of their course the upper six or seven veins give off branches, the **costo-axillary veins,** which ascend towards the axilla and open into either the long thoracic or the thoraco-epigastric vein and so into the axillary, and, as it approaches the vertebral column behind, each vein receives a dorsal branch (**ramus dorsalis**) which accompanies the spinal branch of the intercostal artery and returns the blood from the skin and muscles of the back and also from the spinal column and its contents, this latter drainage being by means of a spinal branch (**ramus spinalis**) which connects with the intervertebral veins (page 898).

Their posterior termination varies considerably in different individuals, especially as regards the upper members of the series. It may be supposed that primarily all the intercostal veins of the right side opened into the azygos vein and all of those of the left side into the hemiazygos or accessory hemiazygos, and this condition holds in the adult with all but the upper two or three veins. On the right side the vein of the first space—that of the second space sometimes uniting with it—frequently accompanies the superior intercostal artery as a **right superior intercostal vein,** and opens above into either the right innominate or one of its branches, usually the vertebral; on the left side the vein of the first space opens into the left innominate vein, being sometimes termed the **accessory left superior intercostal vein,** while the veins of the second, third, and sometimes the fourth spaces unite to a common trunk which crosses the arch of the aorta and opens into the left innominate vein, forming the **left superior intercostal vein.** It is to be noted that this last is connected with the accessory hemiazygos vein and really represents, in part at least, its upper portion,—a fact which is all the more evident from its frequent connection by means of a fibrous cord with the oblique vein of the left auricle; and, furthermore, it may also be pointed out that the veins of the second, third, and sometimes the fourth spaces of the right side usually unite to a common trunk which opens into the azygos vein.

The principal tributaries and connections of the intercostal veins have already been mentioned, but there remain to be described the interesting arrangement shown by the valves in those veins which connect anteriorly with the internal mammary or musculo-phrenic veins. So far as this arrangement is concerned, each vein may be regarded as consisting of three portions: (1) an anterior portion, in which the concavities of the valves look towards the internal mammary or musculo-phrenic veins; (2) a posterior portion, in which the valves look towards the azygos or hemiazygos veins; and (3) an intermediate portion, which is destitute of valves. As a result of this arrangement the blood of the anterior portion of each vein must pass to the internal mammary veins (page 860), that of the posterior portion to the azygos or hemiazygos, while in the intermediate portion it may pass in either direction. But it is with this intermediate portion that the costo-axillary veins are connected, so that in the upper six or seven veins, in addition to passing partly anteriorly and partly posteriorly, some of the blood takes an ascending direction and empties into the axillary vein.

In the two or three lower veins there is no such double flow, the valves all looking towards the azygos veins. Valves occur at the opening of practically all the intercostals into the azygos veins, the last intercostal forming an exception to this rule, and, furthermore, the valves of the lower veins are apt to be insufficient.

The Spinal Veins.

The spinal veins, which return the blood from the vertebral column and the adjacent muscles and also from the membranes enclosing the spinal cord, present in a high degree the plexiform arrangement which is characteristic of the veins as compared with the arteries. They form a series of longitudinal plexuses which extend practically the entire length of the spinal column, communicating extensively with one another, and may be divided primarily into those which lie external to the spinal canal and those which lie within the canal.

The **external spinal plexuses** (**plexus venosi vertebrales externi**) are two in number, anterior and posterior. The *anterior external plexus* (**plexus venosus vertebralis anterior**) rests upon the anterior surfaces of the bodies of the vertebræ, and presents considerable differences in the amount of its complexity in different portions of the spinal column. In the thoracic and lumbar regions it forms a net-work with large meshes, in the sacral region it is represented by transverse anastomoses between the lateral and middle sacral veins, and in the cervical region it reaches its greatest degree of complexity, forming a close net-work, especially dense above and resting partly upon the bodies of the vertebræ and partly upon the longus colli muscles. At each intervertebral foramen the plexus communicates with the veins issuing from the internal spinal plexuses and also with the posterior external plexus, and in addition sends branches to the vertebral veins in the cervical region and to the rami spinales of the intercostal and lumbar veins in the corresponding regions.

The *posterior external plexuses* (**plexus venosi vertebrales posteriores**) lie partly upon the posterior surfaces of the laminæ of the vertebræ and the ligamenta subflava and partly between the deeper dorsal muscles. As in the case of the anterior plexus, they are more complicated in the cervical than in the thoracic and lumbar regions. In the latter their meshes are somewhat elongated longitudinally, and they communicate with the internal plexuses at the intervertebral foramina and also by branches which traverse the ligamenta subflava, and they have further communications with the anterior external plexus and with the spinal rami of the intercostal and lumbar veins. In the cervical region, in correspondence with the greater differentiation of the dorsal musculature, the plexuses become divided into several layers, and in the region between the occiput and the axis vertebra their deep layers form an especially dense net-work, the *suboccipital plexus*, with which the occipital, vertebral, deep cervical, and posterior external jugular veins communicate. Throughout its course the cervical portion of the plexus communicates with the internal and anterior external plexuses and also with the vertebral vein.

The **internal spinal plexuses** (**plexus venosi vertebrales interni**) are situated in the dura mater lining the spinal canal and are much closer than the external plexuses. The veins which form them have a general longitudinal direction and anastomose abundantly, but nevertheless four subordinate longitudinal lines of vessels can be recognized, two of which are upon the anterior wall of the spinal canal and two upon the posterior wall.

The *anterior internal plexuses* lie one on each side of the median line on the posterior surfaces of the bodies of the vertebræ and the intervertebral disks, from the foramen magnum to the sacral region. They are composed of rather large veins, between which are frequent anastomoses, and transverse connecting vessels run across the body of each vertebra between the two plexuses, passing beneath the posterior common vertebral ligament. Into these transverse connections open the *basivertebral veins* (**vv. basivertebrales**) which return the blood from the bodies of the vertebræ, traversing these to a certain extent to communicate with the anterior external plexus. The anterior internal plexuses also communicate opposite each vertebra with the posterior internal plexuses, rings of anastomosing veins thus surrounding the spinal canal opposite each vertebra and constituting what are termed the **retia venosa vertebrarum.**

The *posterior internal plexuses* are situated one on either side of the median line on the anterior surfaces of the laminæ and on the ligamenta subflava, through which they send branches to communicate with the posterior external plexus. They are connected by transverse plexuses which complete the retia venosa vertebrarum, and are composed of smaller vessels than the anterior plexuses, and the net-work which they form is more open.

Laterally, at each intervertebral foramen the internal plexuses send branches out from the spinal canal along the nerve-trunks, and by means of these **intervertebral veins** (vv. intervertebrales), which have the form of plexuses at their origin and receive communicating branches from the external vertebral plexuses and from the veins of the spinal cord, the internal plexuses pour their blood into the vertebral, intercostal, lumbar, and lateral sacral veins, the connection with the intercostals being through their rami spinales. Above, the internal plexuses form an especially rich rete or plexus around the foramen magnum and communicate with the occipital, marginal, and basilar sinuses.

Practical Considerations.—The posterior external spinal plexuses, by means of their communication through the intervertebral foramina and the ligamenta subflava with the internal plexuses, may convey infection from without—septic wounds of the back, severe bed-sores, osteitis of the vertebral laminæ—to the interior of the spinal canal. External pachymeningitis has thus originated. In operations upon the spine, these veins bleed so freely that it is often well after severing them upon one side to control them by packing and proceed to the exposure of the spine on the opposite side, repeating the packing there. The internal plexuses, interposed between the theca of the cord and the interior walls of the vertebral column, may, as a result of trauma, furnish blood enough to cause compression of the cord. The symptoms are usually relatively slow in developing—as compared with those due to injury to the cord itself or to its vessels—and are referable mainly to the lower spinal segments, the blood gravitating to that portion of the canal.

Hemorrhage may occur within the membranes (hæmatorrhacis), when the blood will likewise tend to gravitate toward the lower end of the cord, and, unless in large amount, may cause no definitely localizing symptoms. Bleeding from the venæ medulli spinales may take place into the substance of the cord (hæmatomyelia), and is most likely to occur in the segments from the fourth cervical to the first dorsal (Thorburn), because of the degree of motion of that portion of the spine, the union toward its base of a fixed and a movable segment, and the frequency with which forces causing excessive flexion or over-extension are applied to the head. If the lesion causes compression only, the paralysis, anæsthesia, etc., will be only temporary. If it is associated with disorganization of the cord, they will be permanent.

The Veins of the Spinal Cord.

The veins of the spinal cord (vv. **medulli spinales**) occur as six longitudinal stems situated upon the surface of the cord and connected by a fine net-work very much as are the arteries. One of these stems traverses the entire length of the cord along the line of the anterior median fissure, and has on either side of it another stem which lies immediately posterior to the line of exit of the anterior nerve-roots. These three stems together form the **anterior medulli-spinal veins** (vv. **spinales externae anteriores**). The **posterior veins** (vv. **spinales externae posteriores**) have a similar arrangement, one lying along the line of the posterior longitudinal fissure and one posterior to each of the lines of entrance of the posterior nerve-roots.

All these stems, together with the plexus which connects them, lie in the pia mater and receive branches (vv. **spinales internae**) from the substance of the cord. From them branches pass out along the nerve-roots to join the intervertebral veins, and at the upper extremity of the cord they join the veins of the medulla oblongata.

THE INFERIOR CAVAL SYSTEM.

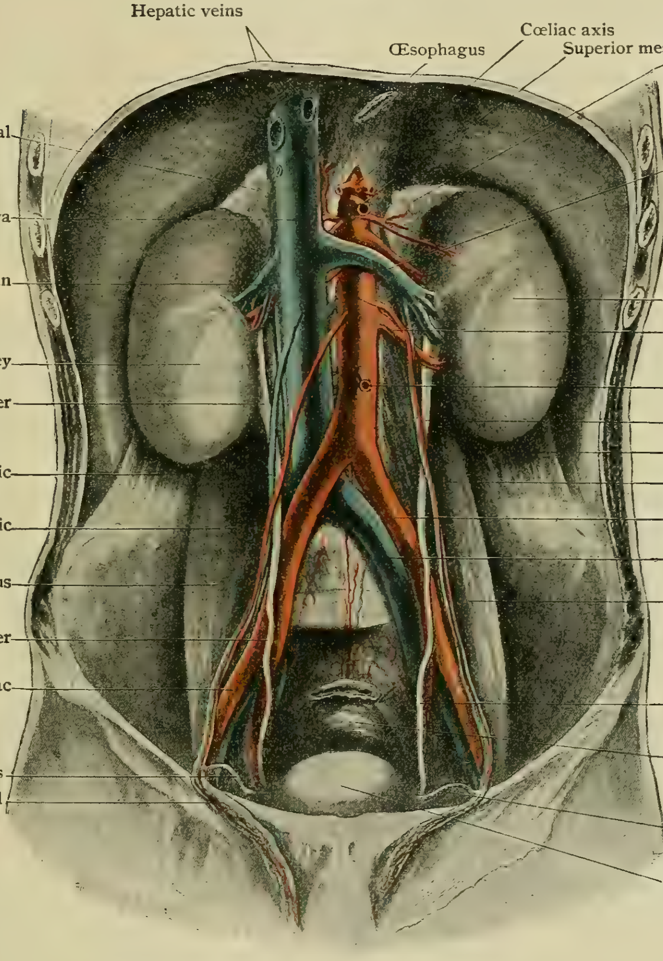
The inferior caval system includes all the veins from the body-wall below the level of the diaphragm; those from the abdominal and pelvic cavities, with the exception of those from the stomach, intestines (except the lower part of the rectum),

pancreas, and spleen ; and those from the lower limb. It receives its name from its principal vessel, the inferior vena cava, which conveys its blood to the right auricle.

The Inferior Vena Cava.

The inferior or ascending vena cava (**vena cava inferior**) (Figs. 765, 766) is formed by the union of the two common iliac veins either on the right side of the intervertebral disk separating the fourth and fifth lumbar vertebræ or on the right side of the fifth lumbar vertebra. From this point it ascends directly upward to the level of the first

Fig. 766.



Inferior vena cava and iliac veins.

lumbar vertebra and there begins to bend slightly to the right to reach the fissure of the liver which separates the Spigelian and right lobes. Passing upward in this fissure, it reaches the diaphragm and perforates the left lobe of the centrum tendineum of that structure, so entering the cavity of the thorax, then bends slightly forward and to the left, and opens into the lower and back part of the right auricle of the heart.

It is the largest vein of the body, measuring at its entrance into the auricle about 33 mm. in diameter. It increases in size from below upward with the accession of its various tributaries, somewhat sudden increases succeeding the entrance into it of its largest tributaries, the renal and hepatic veins. It contains no valves, unless the Eustachian valve guarding its entrance into the auricle be regarded as belonging to it.

Relations.—For convenience in description the vena cava inferior may be regarded as consisting of an abdominal and a thoracic portion. The former, which constitutes by far the greater part of its length, has the following relations. Posteriorly it rests upon the right side of the lumbar vertebræ, upon the origins of the psoas major and minor muscles, and above upon the right crus of the diaphragm; it crosses in its course the right lumbar and right renal arteries. Medially it is in close relation with the abdominal aorta throughout the greater portion of its course, but separates from it slightly above, the right crus of the diaphragm intervening. Laterally it is in contact with the psoas major muscle below, and at about the middle of its course it is in close relation with the inner border of the right kidney. Anteriorly it is covered at its origin by the right common iliac artery and in the lower part of its course by peritoneum. At the level of the third lumbar vertebra it lies beneath the third portion of the duodenum, and immediately above that beneath the head of the pancreas and the main stem of the portal vein, which crosses it obliquely. Finally, it lies in the vena caval fissure of the liver, having to the right the right lobe and to the left the Spigelian lobe, and being sometimes completely surrounded by liver-tissue, owing to a thin portion of it bridging over the fissure. Throughout this part of its course it is firmly united to the walls of the fissure by fibrous bands.

In its *thoracic portion*, which is quite short, measuring not more than 3 cm. in length, it is in relation at first with the right lung and pleura, and in the upper part is enclosed for about 1.2 cm. in the pericardium.

Variations.—The development of the inferior vena cava (page 927) shows it to be formed by the union of three primarily distinct structures. Its upper part, between the entrance of the hepatic veins and the right auricle, is the upper part of the embryonic ductus venosus, then follows a considerable portion derived from the right subcardinal vein, and, finally, its lower part is formed from the right cardinal vein. Of these embryonic veins the ductus venosus is unpaired, the other two are the right members of paired veins, whose fellows undergo almost complete degeneration.

Anomalies of the vena cava, which are not uncommon, are for the most part explicable as a persistence or modification of the embryonic conditions. Thus, that portion of the vessel which is formed from the right subcardinal and right cardinal may fail to develop, in which case what is termed a persistence of the cardinals occurs. Up to a point above the level of the renal veins the vena cava is represented by two parallel trunks lying one on either side of the aorta, the one receiving the right common iliac vein and the other the left. These represent the abdominal portions of the cardinal veins or, in the majority of cases, more probably the subcardinals, and unite above with the unpaired ductus venosus, which carries their blood to the heart. In other words, such cases are, as a rule, to be regarded as a similar development of both subcardinal veins.

Occasionally, however, the development of the right subcardinal to form the vena cava may proceed as usual, but it fails to make a connection with the ductus venosus, one of its connections with the right cardinal enlarging so that this vein receives the caval blood, carries it through the aortic opening of the diaphragm, and as the azygos vein, empties it into the superior vena cava. The hepatic veins open as usual into the ductus venosus, which passes to the right auricle in the normal manner, and the vena cava inferior is thus represented by two distinct veins, the upper part of the ductus venosus, which in such cases is termed the common hepatic vein (*v. hepatica communis*), and the subcardinal and cardinal portion.

Another variation may be produced by a reversal of the rôles of the two subcardinals in forming the vena cava, the left being the one which develops, while the right degenerates. Such a condition is found in all cases of situs inversus viscerum, but it has also been observed in cases in which there was otherwise a normal arrangement of the organs. In such cases the vena cava in the lower part of its course lies to the left of the aorta instead of to the right, and at the level of the renal arteries it crosses to the right side in front of the aorta, its further course being normal. But just as the lower part of the inferior vena cava, when normally formed from the right subcardinal, may fail to unite with the ductus venosus but retain its primary connection with the azygos, so, too, when formed from the left subcardinal, it may retain its connection with the hemiazygos and drain through that vessel into the azygos and so into the superior vena cava.

These various cases include the principal variations which occur in connection with the vena cava inferior. It may be pointed out that normally connections exist between the azygos vein and the vena cava below the diaphragm; by means of the ascending lumbar veins, and also by the thoraco-epigastric veins, connection is established between tributaries of the inferior cava and the external iliac veins and the axillary vein. By means of these normally subordinate channels opportunity is afforded for the maintenance of the circulation in case of obliteration of the vena cava.

Practical Considerations.—The inferior cava may be ruptured in severe abdominal injuries, as in the case of a weight falling upon, or a wagon passing over, the belly. The site of rupture is most often in the portion lying in the hepatic

fissure. Its relation to the right psoas major muscle has resulted, in cases of psoas abscess, in ulceration and opening of the vein, with fatal hemorrhage. Its relation to the inner border of the right kidney has resulted in its compression by a movable kidney, or by a cancerous growth of the kidney, causing caval thrombosis, a condition which has also been noted in connection with chronic nephritis and with infarction of the renal parenchyma. Its relation to the liver results, in some cases of hepatic enlargement, in compression of the vena cava with œdema of the lower limbs, and other symptoms of obstruction. Its close proximity to the lower end of the bile-duct necessitates caution in cutting operations for the removal of impacted stones from the duct (choledochotomy) (page 1732). Enlargement or growth involving the head of the pancreas may compress the cava sufficiently to cause obstructive symptoms, and the nearness of the vein constitutes one of the very serious obstacles to removal of pancreatic tumors. In ureterotomy or other operation on the right ureter, the close relationship of the vena cava at the point of crossing should be remembered. Thrombosis of the cava, from whatever cause, though it may extend the entire length of the vessel, is apt to be limited to a portion of the vessel, as that between the renal veins and the auricle, or that extending from the iliac veins to the renal veins. The collateral circulation after occlusion may be carried on through the saphenous, superficial abdominal, spermatic, pudic, and deep epigastric veins, and the obturator, inferior mesenteric, external mammary, and azygos veins.

Tributaries.—In addition to the common iliac veins by whose union it is formed, the vena cava inferior receives a number of tributaries from the abdominal walls and organs. These may be arranged into two groups according as they drain the *parietes* of the abdomen (**radices parietales**) or its *viscera* (**radices viscerales**). Of the former there are : (1) the *inferior phrenic* and (2) the *lumbar* veins, and of the latter (3) the *hepatic*, (4) the *renal*, (5) the *suprarenal*, and (6) the *spermatic* or *ovarian* veins.

1. **The Inferior Phrenic Vein.**—The inferior phrenic (**v. phrenica inferior**) is a paired vein which corresponds to the similarly named artery. It is formed by the union of a number of tributaries which ramify upon the under surface of the diaphragm, and opens into the vena cava just before it passes through the diaphragm. It receives tributaries from the upper portion of the suprarenal capsule, and the left vein, by the enlargement of an anastomosis of its suprarenal tributaries with the suprarenal vein, may open through the latter into the left renal vein. The right vein occasionally opens into the right hepatic vein.

2. **The Lumbar Veins.**—The lumbar veins (**vv. lumbales**) are usually four in number on each side, and accompany the corresponding arteries, lying above them. They resemble closely in their relations and tributaries the intercostal veins, of which they are serial homologues. Each vein arises in the muscles of the abdominal wall and passes backward and inward towards the vertebral column, passing beneath the psoas muscle. Shortly before reaching the vena cava it receives a **ramus dorsalis.** This has its origin in the dorsal integument and muscles, communicating with the posterior external spinal plexus, and receives a **ramus spinalis** which communicates with one of the lumbar intervertebral veins and so with the internal spinal plexuses. The veins then continue their course towards the vena cava, those of the left side passing beneath the abdominal aorta, and they open into the posterior surface of the vena cava.

As it passes upon the lateral surface of its corresponding lumbar vertebra, each of the three lower veins is connected with the one above by an ascending stem, which also places the lowest vein in communication with the ilio-lumbar or the common iliac vein, while from the uppermost vein it is continued on upward to join with the azygos or hemiazygos as the case may be. This ascending stem is the **ascending lumbar vein** (**v. lumbalis ascendens**), and is of especial interest as forming an important collateral channel between the inferior and superior venæ cavæ.

Each lumbar vein possesses one or two valves in its course, and sometimes also valves at its entrance into the vena cava. The concavities of these valves are directed towards the vena cava, but the valves are nearly always insufficient and

consequently will not prevent a flow of blood from the vena cava outward to the ascending lumbar veins in cases of occlusion of the upper part of the vena cava.

3. **The Hepatic Veins.**—The hepatic veins (**vv. hepaticae**) (Fig. 765) return the blood which has been carried to the liver both by the hepatic artery and by the portal vein. They are two or three in number, and are formed by the union of the intralobular veins of the liver (page 920). They emerge from the substance of the liver at the upper part of the groove in which the vena cava lies, and, passing obliquely upward, enter that vessel at an angle shortly before it passes through the diaphragm.

One of the hepatic veins drains the substance of the right lobe of the liver, the other, when there are but two, the remaining lobes. Quite frequently this second or left vein is replaced by two vessels, one of which drains the left lobe alone, while the other drains the Spigelian and quadrate lobes. Usually, in addition to these principal veins, a varying number of *small hepatic veins* occur, which make their exit from the liver-substance on the walls of the groove for the vena cava and open directly into that vessel without joining the principal hepatic veins.

The hepatic veins possess no valves in the adult, and are characterized by the thickness of their walls, which are provided with both circular and longitudinal muscles.

Variations.—Occasionally the right vein, more rarely the left, perforates the diaphragm and opens either into the thoracic portion of the inferior vena cava or else directly into the right auricle. The two (or three) veins sometimes unite to a single trunk before joining the vena cava, and this trunk has been observed to penetrate the diaphragm and open directly into the right auricle without communicating with the vena cava.

4. **The Renal Veins.**—The renal veins (**vv. renales**) (Fig. 766) are two in number, one returning the blood from each kidney. Each vein is formed at the hilum, or some little distance from it, by the union of from three to five branches which come from the kidney substance, and is directed medially and slightly upward, lying in front of the corresponding artery. On account of the position of the vena cava to the right of the median line, the left vein is somewhat longer than the right, and passes in front of the abdominal aorta, just below the origin of the superior mesenteric artery, to reach its point of entrance into the vena cava, this point being usually a little higher than that of the right vein.

Tributaries.—In addition to the vessels by whose union it is formed, each renal vein receives (*a*) an **inferior suprarenal vein** from the lower part of the suprarenal capsule, accompanying the corresponding artery; (*b*) **adipose veins**, which pass transversely across both surfaces of the kidney, taking their origin in its adipose capsule; (*c*) a **ureteric vein**, frequently more or less plexiform in structure, which returns the blood from the upper part of the ureter, anastomosing below with the ureteric tributaries of the spermatic vein. In addition, the left renal vein receives the left spermatic (ovarian) and the left middle suprarenal veins, both of which will be considered with their fellows of the opposite side.

The adipose veins ramifying in the kidney fat penetrate the renal fascia and so come into connection with the tributaries of the lumbar veins, and they also send branches to the spermatic or ovarian veins. A more important communication is, however, made through a vein which arises from the lower surface of each renal and empties on the right side into the first lumbar vein, while on the left side it bifurcates, sending one branch downward to the first lumbar and the other upward to open into the hemiazygos. Since valves occur but rarely in the renal vein, and its tributaries are likewise either without valves or with insufficient ones, the circulation of the kidney may be maintained by means of these communications of the renal veins, even in cases of obliteration of the vena cava inferior in its upper portion.

Variations.—The renal veins are occasionally replaced by from two to seven vessels which open independently into the vena cava,—a condition which probably depends upon the failure of the vessels from the different portions of the kidneys to unite to a common stem. Accessory veins, which communicate with the vena cava below the level of the renals or even with the common iliac, sometimes occur, but more rarely than the similar arteries. The left renal vein has been observed in several cases to pass almost vertically downward parallel to the vertebral column, opening into the vena cava at the level of the fourth lumbar vertebra.

5. **The Middle Suprarenal Veins.**—The middle suprarenal veins (vv. suprarenales) are the principal veins of the suprarenal bodies, from which, however, the superior suprarenals, emptying into the phrenics, and the inferior, opening into the renals, also arise. Each vein occupies a groove on the anterior surface of the suprarenal body, and descends obliquely inward to open on the right side into the inferior vena cava above the right renal, and on the left side into the left renal.

6*a*. **The Spermatic Veins.**—The spermatic veins (vv. spermaticae) begin at the internal abdominal ring, whence they pass upward and inward along with the spermatic arteries and are the continuation upward of the venous plexuses which surround the spermatic cords.

Each of these plexuses has its origin in the **testicular veins** (vv. testiculares) which return the blood from the tunica albuginea testis and from the seminiferous tubules, these latter branches passing towards the hilum of the organ in the trabeculæ. They make their exit from the testis at about the middle of its superior border, and are joined very shortly by the veins of the epididymis. They are then continued up the spermatic cord in the form of from ten to twenty flexuous stems, which anastomose abundantly to form what is termed the **pampiniform plexus** (plexus pampiniformis), surrounding the spermatic artery. As the cord enters the inguinal canal the plexus is reduced to some three or four stems, which, at the internal abdominal ring, become the spermatic veins.

These are two or three stems which anastomose abundantly with one another and consequently present a plexiform arrangement. They surround the abdominal portion of the spermatic artery and, shortly before reaching their termination, unite to a single stem, which on the right side opens at an acute angle into the vena cava inferior below the right renal vein, while on the left side it opens almost at a right angle into the lower border of the left renal vein.

The spermatic veins proper possess no valves, except that there is usually a pair at the entrance of the right vein into the vena cava. In the stems of the pampiniform plexus, however, valves are usually to be found, but they are very frequently insufficient.

Tributaries.—The spermatic veins receive a **ureteric branch** from the lower part of the ureter and also **peritoneal branches** and **renal branches** from the adipose capsule of that organ. In the scrotum the pampiniform plexus makes connections with the branches of the external pudic veins, and at their entrance into the external abdominal ring the two plexuses of opposite sides are connected by transverse anastomoses which pass in front of the symphysis pubis. A deeper transverse anastomosis also occurs between the two spermatics as they emerge from the internal abdominal rings, and they communicate by means of their peritoneal branches with the branches of the right and left colic veins.

Variations.—Occasionally the left vein as well as the right opens directly into the vena cava, and in cases in which that vessel is situated upon the left side it is the left vein which opens directly into it, the right one opening into the right renal vein. They communicate sometimes on one side or the other with a lumbar vein or with the middle suprarenal, and the left vein has been observed to open into the hemiazygos.

The spermatic veins are very apt to become varicose, and it is well known that this condition is more apt to occur in the left vein than in the right. Various reasons have been assigned for this difference in the two veins, the chief of these being (1) that the left vein opens at practically a right angle into the renal, while the right opens at an acute angle into the vena cava; (2) the left vein is destitute of valves at its opening into the renal, while the right one usually possesses a pair at its orifice; and (3) that the left vein in its course up the abdominal wall lies beneath the sigmoid colon, while the right has only coils of the small intestine with their more fluid contents in front of it.

6*b*. **The Ovarian Veins.**—The ovarian veins (vv. ovaricae) correspond to the spermatic veins of the male. They take their origin from the veins which issue at the hilum of the ovary and are also connected by wide anastomoses with the veins of the fundus of the uterus. They form a close plexus, the **pampiniform plexus** (plexus pampiniformis), which accompanies the ovarian artery between the two layers of the broad ligament parallel with the Fallopian tube, receiving branches from the latter structure and from the round ligament of the

uterus. Leaving the broad ligament with the ovarian artery, they ascend along that vessel, the number of trunks becoming reduced to two and eventually to one, and they open above in the same manner as the spermatic veins, the right one into the inferior vena cava and the left one into the left renal vein. They possess no valves.

Their variations are essentially similar to those presented by the spermatic veins.

Practical Considerations.—*The Tributaries of the Inferior Cava.*—In a case of occlusion of the inferior cava by thrombus extending from the renal vein to the right auricle, the *phrenic* and *renal* veins opened into the *lumbar* and azygos veins, the blood of the abdomen thus gaining the superior cava (Allen).

The intralobular branches of the *hepatic* veins may be the source of profuse hemorrhage in cases of wound or rupture of the liver, because (*a*) they are thin-walled; (*b*) they are not encircled by cellular tissue, but are closely attached to the liver substance and thus cannot collapse or retract, a condition which also predisposes to the entrance of air into the divided veins; (*c*) they are valveless, and the main trunks open direct into the vena cava, any obstruction of which would therefore result in the escape of great quantities of blood; (*d*) the flow in the main trunks—from the vein to the cava—is influenced by the movements of the diaphragm, the descent of this muscle tending to constrict the opening through which the veins pass, and thus to obstruct the current and favor bleeding. Hemorrhage from the liver after a wound or during an operation is very difficult to arrest by ligature on account of the thinness of the walls of the intralobular veins and the friability of the liver tissue itself. It is usually controlled by gauze-pressure or by the galvano-cautery. The branches of the portal vein may also bleed freely, but are surrounded by a quantity of lax cellular tissue, as they run in the "portal canals" with the branches of the biliary ducts and of the hepatic artery, and can thus retract or collapse when torn or divided. Moreover, the blood-pressure within the portal vein is low, favoring the spontaneous arrest of hemorrhage. In obstruction of the common duct, preventing the escape of bile into the intestine, the radicles of the hepatic veins take up the bile-stained exudate that results from the increased intra-hepatic tension. Its entrance into the general circulation through the vena cava gives rise to jaundice.

The relative shortness of the right *renal* vein occasionally adds to the difficulties of a right-sided nephrectomy, the pedicle—the vein, artery, ureter, etc.—being shorter and less easily controlled by ligature. As the veins are subject to variation as well as the arteries—though less frequently—supernumerary or misplaced vessels should be carefully looked for. They may be found emerging from the kidney at either pole, or from the hilum behind the pelvis. Fatal results have followed the failure, during a nephrectomy, to find and secure such aberrant vessels. At times the left renal vein passes behind the aorta, to which occurrence may be attributed the greater frequency of hyperæmia of the left kidney (Allen). The renal veins may be obstructed by pressure from retroperitoneal growths, or—in the supine position—from movable abdominal tumors or the gravid uterus, or from traction caused by displacements of the kidney itself, or as a result of congestion in the cardio-pulmonary system, as in pneumonia or valvular heart disease. By whatever cause produced, the congestion, if sufficiently long-continued, may give rise to a form of chronic interstitial nephritis. The communication (*vide supra*) between the renal veins and the first lumbar vein and—on the left side—the hemiazygos vein, accounts for the undoubted good effect often produced in renal congestions by counter-irritation, blisters, cupping, or leeching in the loin.

The *spermatic* veins are of chief practical interest in their relation to varicocele. The anatomical reasons for the frequency of this condition, and for its occurrence by preference on the left side, are given on page 1961.

The veins of the pampiniform plexus proper are usually distinct from those which accompany the vas deferens and its artery. In excision of the former set for varicocele, the vas deferens is always pushed to the rear and held out of harm's way. It carries with it its artery and veins, and the anastomotic communications of the former with the spermatic artery—almost always cut or tied with its venous plexus—and with the scrotal arteries suffice to maintain the nutrition of the testis, while the

veins of this smaller and posterior group enlarge to carry on the return circulation. Elevation is of especial value in testicular inflammation, as the dependent position of the spermatic veins and their lack of adequate support greatly intensify the engorgement and venous obstruction of inflammatory processes.

THE COMMON ILIAC VEINS.

The common iliac veins (**vv. iliacae communes**) (Fig. 765) are two in number, and are formed opposite the sacro-iliac articulations by the union of the internal and external iliac veins. They pass upward, converging as they go, and unite at about the level of the intervertebral disk between the fourth and fifth lumbar vertebræ to form the vena cava inferior.

Since their point of union lies somewhat to the right of the median line, the right vein is shorter than the left and its course is more directly upward. Neither vein possesses valves.

Relations.—The union of the two veins takes place beneath the right common iliac artery, and the right vein, at its origin, lies behind that vessel, although, since its course is more vertical than that of the artery, it gradually comes to lie somewhat lateral to it above. The left vein near its termination is crossed from without inward by the right common iliac artery, and throughout its course lies medially to the left common iliac artery and on a plane somewhat posterior to it.

Variations.—Occasionally the external and internal iliac veins do not unite to form a common stem, but open directly into the inferior vena cava. This may occur on one or both sides.

Tributaries.—In addition to the external and internal iliacs, by whose union they are formed, the common iliacs receive but a single tributary, the **middle sacral vein** (**v. sacralis media**), and this opens into the left vein. It accompanies the middle sacral artery, and in the lower part of its course it is frequently double, one vessel lying on each side of the artery. Opposite each sacral vertebra it receives a transverse connecting branch from the lateral sacral veins and so forms with these what is termed the **anterior sacral plexus.** At its origin it communicates with the hemorrhoidal veins.

THE INTERNAL ILIAC VEIN.

The internal iliac vein (**v. hypogastrica**) (Fig. 767) of each side is a short but rather large vessel, which accompanies the internal iliac artery, lying to its medial side and in a plane somewhat posterior to it. It extends from the neighborhood of the great sacro-sciatic foramen to the level of the sacro-iliac synchondrosis, where it unites with the external iliac to form the common iliac vein.

Tributaries.—Its tributaries correspond in general with the branches of the internal iliac artery, but those which arise in the pelvic viscera present the peculiarity that they take their origin from more or less extensive plexuses which communicate with one another. The stems which pass from these plexuses to the internal iliac also anastomose to a considerable extent, the result being that it is not possible in all cases to recognize definite veins corresponding to the visceral arteries.

The following are the tributaries that are, as a rule, to be recognized : (1) the *gluteal*, (2) the *lateral sacral*, (3) the *ilio-lumbar*, (4) the *sciatic*, (5) the *internal pudic*, (6) the *obturator*, (7) the *middle hemorrhoidal*, (8) the *uterine*, and (9) the *vesical* veins.

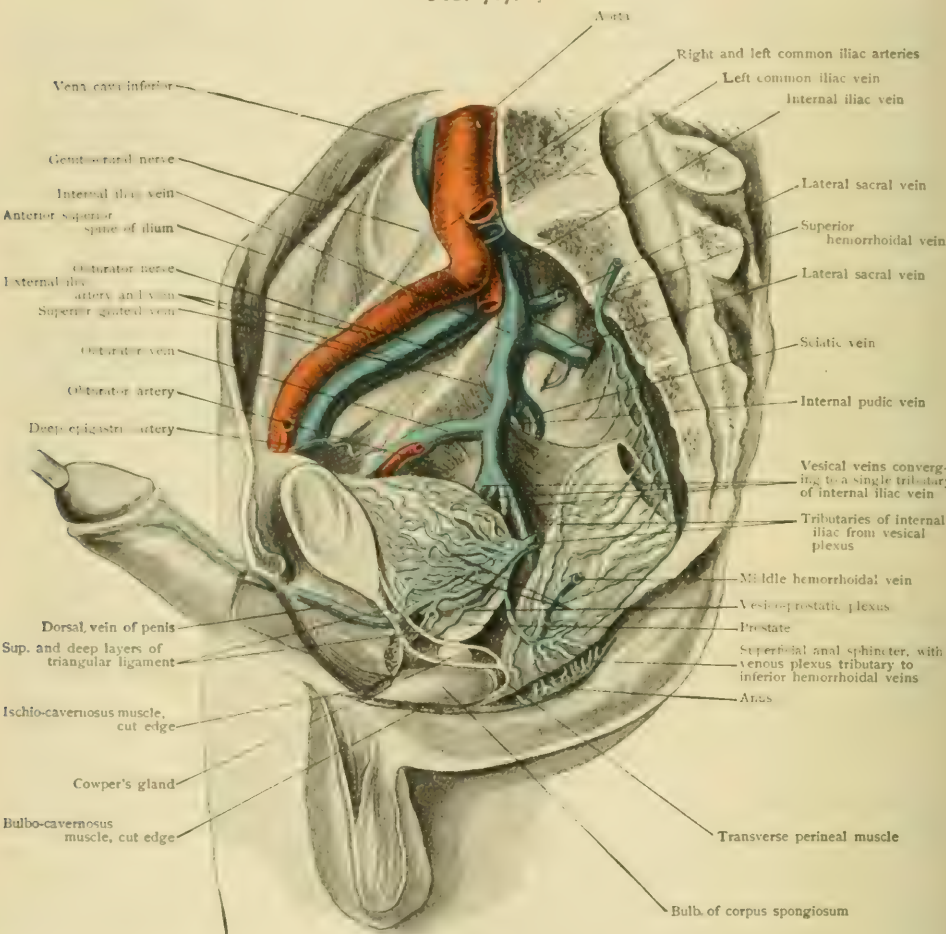
1. **The Gluteal Vein.**—The gluteal vein (**v. glutaea superior**) accompanies the artery of the same name. Throughout its extrapelvic course its tributaries accompany the branches of the artery as valved venæ comites, and at the upper part of the greater sacro-sciatic foramen the veins accompanying the two main branches of the artery unite to form a double trunk, united by numerous anastomoses. This trunk, which is occasionally single, passes through the greater sacro-sciatic foramen above the pyriformis muscle and, after a short intrapelvic course, opens into the internal iliac vein.

Where they pass through the greater sacro-sciatic foramen both artery and vein are surrounded by a dense connective tissue which renders their separation difficult and brings it about that the lumen of the vein remains patent when emptied of blood.

2. **The Lateral Sacral Veins.**—The lateral sacral veins (**vv. sacrales laterales**) are usually double, and pass upward with their arteries upon the anterior surface of the sacrum just medial to the anterior sacral foramina, and open above either directly into the internal iliacs or into the gluteal veins. As they pass each sacral foramen they receive tributaries from the internal spinal plexuses, and opposite each sacral vertebra are connected by transverse branches with the middle sacral veins, these anastomoses forming the *anterior sacral plexus*.

3. **The Ilio-Lumbar Vein.**—The ilio-lumbar vein (**v. iliolumbalis**) follows the course of the corresponding artery and its branches and is richly supplied with

FIG. 767.



Veins of pelvis, viewed from left side.

valves. Its lumbar tributary receives some of the lower intervertebral veins and occasionally the last lumbar, and anastomoses with the lower portion of the ascending lumbar vein. The iliac tributary, which begins over the crest of the ilium and in the substance of the iliacus muscle, makes anastomoses with tributaries of the deep circumflex iliac vein and thus establishes an important collateral venous path between the external and internal iliacs.

The main stem of the vein is a single trunk which opens into the internal iliac or occasionally into the common iliac.

4. **The Sciatic Vein.**—The sciatic vein (**v. glutaea inferior**) of either side of the body has essentially the same course as the corresponding artery. Its extrapelvic

tributaries are venæ comites of the branches of the artery, and its usually single main stem passes through the greater sacro-sciatic foramen below the pyriformis to empty into the internal iliac.

Anastomoses of comparatively large calibre occur between the extrapelvic portions of the sciatic vein and the internal circumflex and first perforating tributaries of the deep femoral vein, thus establishing a collateral venous path between the tributaries of the internal and external iliacs.

5. **The Internal Pudic Vein.**—The internal pudic vein (**v. pudenda interna**) is associated throughout the greater part of its course with the artery of the same name. It differs, however, somewhat in its origin, since it is not the direct continuation of the dorsal vein of the penis (or clitoris), although it communicates with that vessel by a small branch immediately below the symphysis pubis, but is rather the continuation of the veins of the corpus cavernosum which accompany the artery to that structure. It is throughout the most of its length double, anastomoses between the two stems surrounding the internal pudic artery. It has its origin between the two layers of the triangular ligament of the perineum and passes backward into the ischio-rectal fossa, lying with the artery at the side of that cavity in a canal (*Alcock's canal*) formed by a splitting of the lower edge of the obturator fascia. It leaves the ischio-rectal fossa by the lesser sacro-sciatic foramen and, curving around the spine of the ischium, enters the pelvis through the lower part of the greater sacro-sciatic foramen and empties into the internal iliac.

In addition to the communication with the dorsal vein of the penis (or clitoris) already mentioned, the internal pudic vein makes near its origin a connection with the pudendal plexus and, as it curves over the spine of the ischium, with the sciatic vein.

It possesses several valves arranged in a rather characteristic manner. Throughout its course through the perineum it is valveless, but both its terminal portion and its communication with the pudendal plexus possess valves whose concavities look in the one case towards the internal iliac and in the other towards the plexus. Blood contained in the perineal portion of the vein may flow, therefore, either towards the internal iliac directly or to the pudendal plexus (Fenwick), and the communication with the latter cannot well be regarded as the origin of the vein, as is sometimes done.

Tributaries.—In addition to (*a*) the **vein of the corpus cavernosum** (**v. profunda penis vel clitoridis**) already mentioned, the internal pudic vein receives numerous tributaries which correspond with the branches of the artery. Among these may be mentioned: (*b*) the **veins of the bulb** (**vv. bulbi urethrae**), which are quite numerous and issue from the bulb of the urethra or from the bulbus vestibuli in the female, these latter vessels being quite large; (*c*) the **superficial perineal veins** (**vv. scrotales posteriores**), which return the blood from the integument and superficial muscles of the perineum and from the posterior surface of the scrotum and the posterior portion of the labia majora, anastomosing in these structures with the tributaries of the external pudic veins; (*d*) the **inferior hemorrhoidal veins** (**vv. haemorrhoidales inferiores**), which traverse the ischio-rectal space from the neighborhood of the anus, where they make communications with the hemorrhoidal plexus of the rectum.

6. **The Obturator Vein.**—The obturator vein (**v. obturatoria**) accompanies the obturator artery and shares in the variations which that vessel presents (page 814). It takes its origin in the adductor muscles of the thigh, its tributaries uniting to form an internal and an external branch, which curve around the margins of the obturator foramen. The vein formed by the union of these two branches passes through the opening in the upper part of the obturator membrane and passes across the lateral pelvic wall, lying immediately below the artery. It opens, as a rule, into the internal iliac vein.

Its communications are somewhat extensive and important. Its external tributary branch receives branches from the scrotum or labia majora and through these communicates with the external pudic veins. At its passage through the opening in the obturator membrane it receives branches from the obturator plexus, which cover both surfaces of the membrane and drain the obturator muscles, and also a branch which passes downward and inward upon the inner surface of the os pubis, frequently communicating above with the pubic tributary of the deep epigastric vein.

Additional communications are made with the vesico-prostatic (vesico-vaginal) plexus and the internal pudic vein, and also with the internal circumflex branch of the deep femoral and with the sciatic.

7. **The Middle Hemorrhoidal Vein.**—The middle hemorrhoidal vein (v. **haemorrhoidalis media**) has its origin in the hemorrhoidal plexus of the rectum, and after receiving tributaries from the seminal vesicles, the prostate gland, and the urinary bladder in the male and from the vagina in the female, opens into the internal iliac or one of its tributaries. It is a comparatively large vein, and of importance in that it forms through its connection with the hemorrhoidal plexus a communication between the portal and inferior caval systems of veins.

The **hemorrhoidal plexus** (**plexus haemorrhoidalis**) which surrounds the rectum is composed of two venous net-works, one of which, the *internal hemorrhoidal plexus*, lies in the submucosa of the rectum, while the other, the *external hemorrhoidal plexus*, rests upon its outer surface. The internal plexus is characterized in the adult, in that portion of it which lies just above the anal opening, by the occurrence of round or elongated bunches (**glomera haemorrhoidalia**) formed by a number of small veins coiled together into a mass resembling somewhat a Malpighian glomerulus. Upon the veins which form the glomera, or upon those extending between adjacent glomera, ampullar dilatations occur which have been regarded both as the cause and as the result of the glomera formation. Be that as it may, the internal hemorrhoidal plexus presents in the adult, slightly above the anus, a distinct band characterized by the occurrence of glomera and dilatations, and forming what is termed the **annulus haemorrhoidalis.**

The internal plexus opens partly at the anal orifice into the branches of the inferior hemorrhoidal veins and partly, by branches which traverse the muscular coats of the rectum, into the external plexus. This has three sets of **efferent veins**: (1) the inferior hemorrhoidals, which open into the internal pudic; (2) the middle hemorrhoidals, which pass to the internal iliac or one of its branches; and (3) the superior hemorrhoidal, which leads to the inferior mesenteric and so to the portal vein. The external plexus also communicates with the vesico-prostatic plexus in the male and the vaginal plexus in the female.

8. **The Uterine Vein.**—The uterine vein (v. **uterina**) arises opposite the external os uteri from the plexus utero-vaginalis. It is at first a double vein, its two trunks accompanying the uterine artery, and where that vessel crosses the ureter one of the trunks passes with the artery in front of the duct and the other behind it. The two trunks then usually unite to a single vein, which passes into the internal iliac, frequently receiving the vesical veins or the obturator.

The **utero-vaginal plexus** is formed by the veins which return the blood from the uterus and vagina. The veins in the substance of the uterus are exceedingly thin-walled, appearing as clefts in sections, and form a more or less distinct layer (**stratum vasculare**) in the muscular wall of the organ. From this vessels pass to both the anterior and posterior surfaces of the organ and follow a course which is outward and more or less downward towards the lateral borders, where, between the two layers of the broad ligament, they form a rich plexus, the **uterine plexus,** the vessels of which converge towards the origin of the uterine vein, opposite the external os uteri. The **vaginal veins** form a rich plexus in the walls of the vagina, the emissaries from which are directed laterally and more or less upward, forming along the lateral walls of the organ a rich **vaginal plexus** whose stems also converge to the uterine vein at the level of the external os uteri. These two plexuses, the uterine and vaginal, are continuous at the level of the external os uteri and form together the extensive plexus utero-vaginalis.

At the fundus of the uterus this plexus makes abundant connections with the pampiniform plexus of the ovarian veins and with the funicular veins which accompany the ligamentum teres. Lower down, throughout its uterine portion, it receives affluents from the plexus of veins which occurs between the layers of the broad ligament, and the lower part of its vaginal portion makes connections anteriorly with the vesico-vaginal plexus and posteriorly with the external hemorrhoidal plexus.

9. **The Vesical Veins.**—The vesical veins (**vv. vesicales**) vary somewhat in number, but together represent a vessel of considerable size. They arise at the sides of the bladder from a well-marked plexus which occupies in the male the groove

between the prostate gland and the bladder and is termed the *vesico-prostatic plexus*. In the female the plexus lies at the sides and base of the bladder, and from its relations posteriorly is known as the *vesico-vaginal plexus*. From their origin the vesical veins pass upward, outward, and backward to open into the internal iliac.

The **vesico-prostatic** or **vesico-vaginal plexus** (plexus vesicalis), occupying the position indicated above, is formed principally by the veins which drain the urinary bladder and, in the male, the prostate gland. Posteriorly, in the male, the plexus communicates with the external hemorrhoidal plexus, and in the female with the vaginal plexus, and anteriorly, in both sexes, it communicates extensively with the pudendal plexus. In addition to the drainage which it possesses through the vesical veins, it also drains by way of the obturator veins, branches from it joining those vessels just after they have passed through the obturator foramina.

The **pudendal plexus** (plexus pudendalis), also known as the *plexus of Santorini*, occupies the space between the lower part of the pelvic surface of the symphysis pubis and the anterior surface of the neck of the bladder, becoming continuous posteriorly at the sides with the vesico-prostatic (vesico-vaginal) plexus. Its chief tributary is the **deep dorsal vein of the penis (clitoris)** (v. dorsalis penis vel clitoridis), which is a single large vein (sometimes partly double in the female) which passes along the dorsal mid-line of the penis or clitoris, beneath the deep fascia (Fig. 767), in the groove between the two corpora cavernosa, and has on either side of it one of the two dorsal arteries. It receives branches from the corpora cavernosa and has its origin in two veins which curve from below upward around the base of the glans penis (clitoridis). At the root of the penis (clitoris) it leaves the dorsal surface and perforates the triangular ligament of the perineum, usually just below the border of the subpubic ligament, so entering the pelvis. It then bifurcates, each of the branches passing into the pudendal plexus. Before entering the pelvis it gives off on either side a small branch which unites with the internal pudic vein, thus representing the course of the artery.

In addition to the dorsal vein of the penis (clitoris), the pudendal plexus also receives branches from the internal pudic vein and from the anterior surfaces of the bladder and, in the male, the prostate. It communicates posteriorly and at the sides with the vesico-prostatic (vesico-vaginal) plexus, and through it finds its chief efferents in the vesical veins, although it is also drained by the obturator veins, with each of which it communicates by one or two branches.

The External Iliac Vein.

The external iliac vein (v. iliaca externa) (Figs. 766, 767) begins at Poupart's ligament, where the femoral vein becomes continuous with it, and passes upward, backward, and inward to the level of the sacro-iliac articulation, where it unites with the internal iliac to form the common iliac.

Its course is along the line of junction of the false and the true pelvis, and it lies upon the inner border of the psoas muscle and internal, or in its upper part internal and posterior, to the external iliac artery. Near its termination it is crossed by the internal iliac artery, on the left side almost at a right angle, on the right more obliquely. Valves are present in about 35 veins out of 100, but in a third of such cases they are insufficient.

Tributaries.—The tributaries of the external iliac vein are: (1) the *deep epigastric* and (2) the *deep circumflex iliac* veins.

1. **The Deep Epigastric Vein.**—The deep epigastric vein (v. epigastrica inferior) has its origin above the umbilicus in the substance of the rectus abdominis muscle, where it anastomoses with the superior epigastric vein. It accompanies the deep epigastric artery as two venæ comites which unite below to form a single trunk opening into the external iliac a short distance above Poupart's ligament.

Below the level of the umbilicus the vein is provided with valves whose concavities are directed downward, but above the umbilicus it is said to be destitute of valves. It receives tributaries from the rectus muscle and, as it passes beneath the

internal abdominal ring, from the spermatic cord or round ligament of the uterus. The connections which it makes with other veins are numerous and important. Its connections with the superior epigastric vein have already been noted; by this communication is established between the superior and inferior venæ cavæ. In addition, by means of branches which traverse the sheath of the rectus muscle, it communicates with the subcutaneous and subperitoneal veins of the abdominal wall and with the parumbilical veins, forming through these latter a connection with the portal system of veins. Finally, by means of a pubic branch, which is frequently a tributary of the external iliac rather than of the deep epigastric, it communicates with the obturator vein, and by the enlargement of this communication the obturator vein, just as is the case with the artery, may become a tributary of the deep epigastric.

2. **The Deep Circumflex Iliac Vein.**—The deep circumflex iliac vein (**v. circumflexa ilium profunda**) has the same course as the corresponding artery, which it surrounds in a plexiform manner. It possesses valves and communicates with the iliolumbar veins. Near its termination it becomes a single trunk and opens into the external iliac a little above the deep epigastric; occasionally it opens into the latter vessel.

THE VEINS OF THE LOWER LIMB.

The external iliac vein is the channel by which the blood returning from the lower limb is conveyed to the inferior vena cava and is the direct upward continuation of the femoral vein. Instead, however, of proceeding to a description of this latter vessel and so down the leg, it will be more convenient to begin the account of the veins of the lower limb with those of the foot and proceed upward to the femoral.

As in the upper limb, two practically distinct sets of veins can be recognized in the leg; one set is more or less deeply seated and accompanies the arteries, while the other is superficial and, in the adult, has a course quite independent of the arterial distribution. The deep veins will first be considered.

THE DEEP VEINS.

The Deep Veins of the Foot.

The deep veins of the sole of the foot have their origin in a net-work with more or less distinctly elongated meshes, which occurs upon the plantar surfaces of the digits. These are the **plantar digital veins** (**vv. digitales plantares**), and in the webs of the toes the vessels of each digit unite with those of the neighboring ones to form a series of **plantar interosseous veins** (**vv. metatarseae plantares**) occupying the metatarsal interspaces and forming venæ comites for the plantar interosseous (metacarpal) arteries. Just as the digital veins unite to form the interosseous, they send **dorsal branches** (**vv. intercapitulares**), which unite with the dorsal interosseous veins, and, in addition, make connections with the superficial plantar veins, and might, indeed, be classed with these quite as appropriately as with the deep set.

The plantar interosseous veins pass backward, receiving branches from the neighboring muscles, and open into a venous plantar arch (**arcus venosus plantaris**), formed by the venæ comites of the arterial plantar arch. These are continued posteriorly into the **external plantar veins**, which pass obliquely across the foot along with the corresponding artery and unite behind the inner malleolus with the **internal plantar veins** to form the companion veins of the posterior tibial artery. Both plantar veins give off branches which perforate the plantar aponeurosis and communicate with the superficial plantar veins, and connecting vessels also pass across the sole of the foot between the two veins.

Upon the dorsum of the foot there exist the **dorsal digital veins** (**vv. digitales dorsales**), which, like the corresponding plantar veins, may be equally classified with superficial or deep veins, since they make connections with both sets. In the webs of the toes the vessels of adjoining digits unite to form the four **dorsal interosseous veins** (**vv. metatarseae dorsales**), which occupy the metatarsal interspaces and communicate with the corresponding plantar veins by the intercapitular and perforating

veins. They form the venæ comites of the dorsal interosseous (metatarsal) arteries and open into the companion veins of the metatarsal artery. These, together with the veins accompanying the tarsal arteries, open into the venæ comites of the art. dorsalis pedis, and these in turn are continuous with the venæ comites of the anterior tibial artery.

The Deep Veins of the Leg.

The deep veins of the leg are the venæ comites of the posterior and anterior tibial arteries and their branches. The **posterior tibial vein** (v. tibialis posterior) is formed behind the internal malleolus by the union of the internal and external plantar veins, and consists of two, or in many cases three, veins accompanying the posterior tibial artery. It terminates at the lower border of the popliteus muscle by uniting with the anterior tibial veins to form the popliteal, and possesses in its course from eight to twenty valves. A short distance below the popliteus muscle it receives the **peroneal veins** (vv. peroneae) which accompany the peroneal artery. They are usually of larger calibre than the posterior tibial veins, receiving a larger share of the vessels which come from the posterior crural muscles, and they anastomose with the posterior tibials by frequent transverse branches, and also with the anterior tibials. They possess from eight to ten valves.

The **anterior tibial veins** (vv. tibiales anteriores) are the upward continuation of the venæ comites of the art. dorsalis pedis. They accompany the anterior tibial artery, and are united across the artery by numerous transverse anastomoses. They pass with the artery to the posterior surface of the crus above the interosseous membrane and unite with the posterior tibials to form the popliteal vein. They make communications with both the peroneal and posterior tibial veins by branches which perforate the interosseous membrane, and are furnished, on the average, with about eleven valves.

The Popliteal Vein.

The popliteal vein (v. poplitea) (Fig. 768) is a single trunk formed by the union of the anterior and posterior tibial veins at the lower border of the popliteus muscle, and it extends from that point to the opening in the adductor magnus which transmits the femoral artery. It is throughout closely bound down by dense connective tissue to the popliteal artery, and lies between that vessel and the internal popliteal nerve. Its course, however, is not quite parallel to that of the artery, but in its lower part it is slightly internal to the artery and in its upper part somewhat external to it. The popliteal vein possesses from one to four valves and is directly continuous above with the femoral vein.

In addition to the popliteal vein, the popliteal artery has two other smaller veins accompanying it. The external one (v. comitans lateralis) has its origin from the veins issuing from the outer head of the gastrocnemius and the soleus, and passes upward along the outer surface of the artery to open into the popliteal vein at about the middle of its course. The inner vena comitans (v. comitans medialis) is formed by the veins issuing from the inner head of the gastrocnemius and ascends along the inner side of the artery, making connections with the inferior and superior internal articular veins, to open into the popliteal vein just below the opening in the adductor magnus.

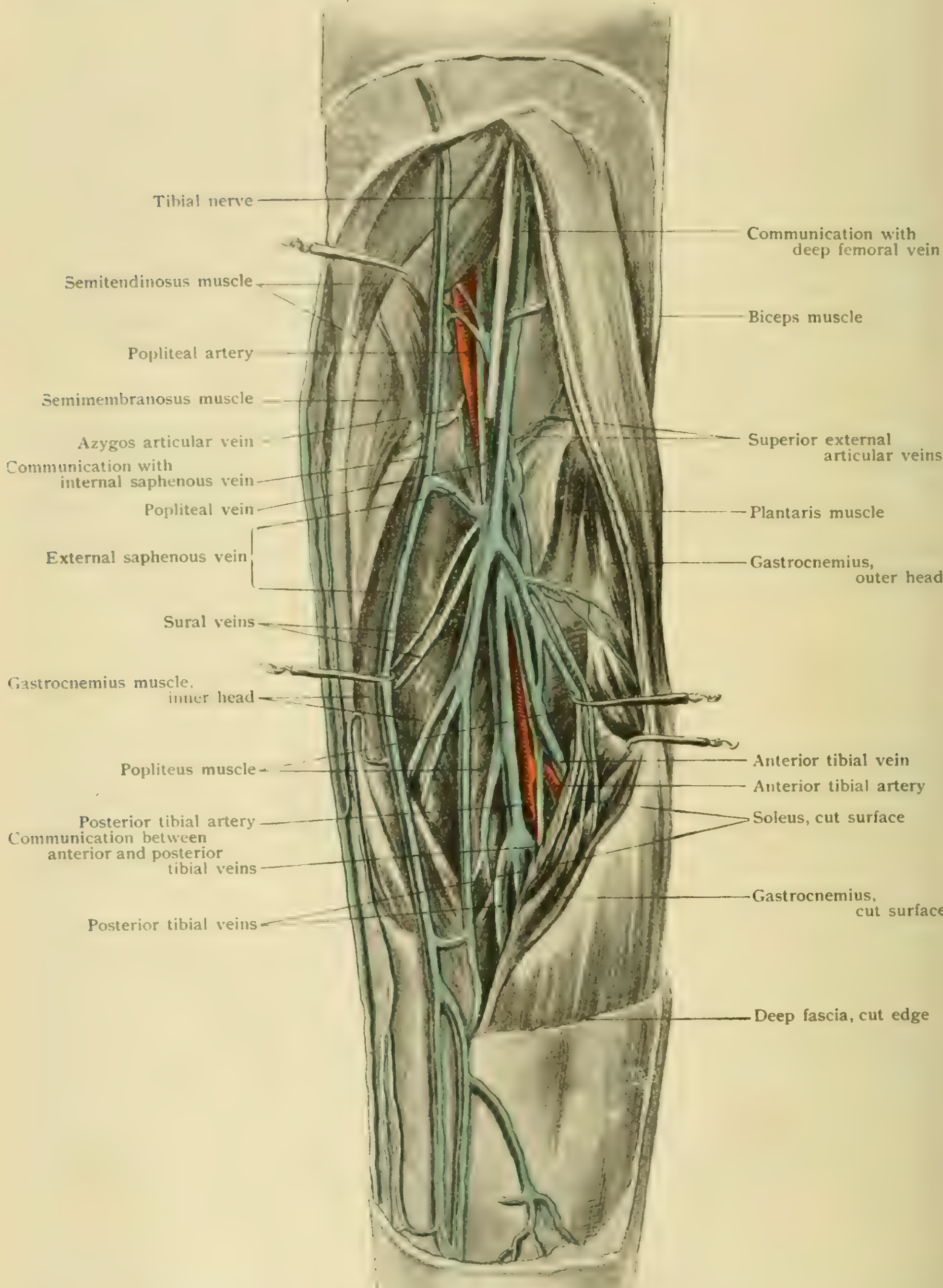
Tributaries.—The majority of the tributaries of the popliteal vein correspond to the branches of the popliteal artery,—that is to say, they are articular and muscular. In addition it receives the short saphenous vein at about the middle of its course.

Variations.—The popliteal vein may be considerably shorter than usual owing to the failure of the tibial veins to unite at the customary level. Not infrequently the vein is double throughout a portion of its course, more rarely throughout its entire length, and it occasionally lies beneath (*i.e.*, anterior to) the artery.

It normally communicates by means of its tributaries with branches of the deep femoral vein, and occasionally this communication becomes so large that the popliteal seems to bifurcate above, one branch becoming continuous with the femoral and the other with the deep femoral. More interesting from the historical stand-point are the rare cases in which the vein

ascends the back of the thigh along with the sciatic nerve, either uniting above with one of the branches of the deep femoral or continuing into the pelvis with the nerve to become a

Fig. 768.



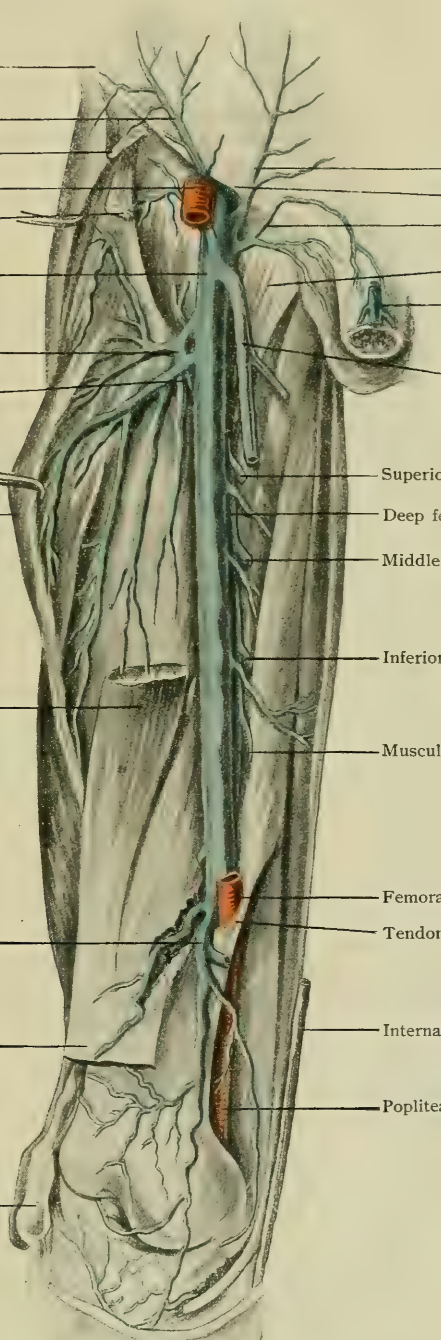
Veins of right popliteal space.

tributary of the internal iliac vein. This last arrangement recalls an anomaly occasionally presented by the sciatic artery (page 815), and is probably due to the same embryological conditions.

The Femoral Vein.

The femoral vein (**v. femoralis**) (Fig. 769) accompanies the femoral artery from the opening in the adductor muscle through Hunter's canal and Scarpa's triangle to its beginning at the lower border of Poupart's ligament. It is a single

Fig. 769.



Right femoral vein and its tributaries.

trunk and is the direct continuation of the popliteal vein below, and it terminates by becoming continuous with the external iliac vein above. In its lower part it lies slightly external to the artery, but throughout the greater part of its course it rests upon the posterior surface of the artery and is enclosed in a common sheath with it. Above it inclines somewhat inwardly and comes to lie upon the inner surface of the artery, between it and the femoral canal. It possesses from one to five pairs of valves, the most constant pair, present in 81 per cent. of cases, being situated in the upper 5 cm. of the vein and consequently controlling the flow from all the veins of the lower limb.

Tributaries.—The tributaries of the femoral vein correspond with the branches of the femoral artery, although some of them communicate with the vein only indirectly, opening primarily into the long saphenous vein, which is itself a tributary of the femoral. Thus, the long saphenous usually receives the external pudic, superficial circumflex iliac, and superficial epigastric veins, and these will be described later with the saphenous veins. Of the remaining tributaries, (1) the *deep femoral*, (2) the *venæ comites*, and (3) the *anastomotica magna*, the first two deserve special mention.

1. **The Deep Femoral Vein.**—The deep femoral vein (**v. profunda femoris**) accompanies the deep femoral artery, and, like it, receives as tributaries **perforating veins** (**vv. perforantes**) which take their origin upon the posterior surface of the adductor muscles and anastomose with one another, with tributaries of the popliteal below and with the sciatic above. The lowest perforating vein, which represents the actual beginning of the deep femoral, has communicating with it one of the terminal branches of the short saphenous vein. The deep femoral vein also receives the **internal** and **external circumflex veins** (**vv. circumflexa femoris medialis et lateralis**) which accompany the corresponding arteries as their venæ comites, the internal circumflex anastomosing with the sciatic and obturator veins and so providing for a possible collateral circulation between the internal and external iliac veins. The deep femoral opens into the femoral usually about 4–5 cm. below Poupart's ligament, but not infrequently at a somewhat higher level, and the circumflex veins may open directly into the femoral instead of into the deeper vein.

2. **The Venæ Comites.**—The venæ comites of the femoral artery are two or three small stems which run parallel with the artery and vein through Hunter's canal. One lies to the inner side of the artery (**v. comitans medialis**) and the other to the outer side (**v. comitans lateralis**), and when a third is present it accompanies the long saphenous nerve. They communicate with, or in some cases receive, the veins issuing from the adjacent muscles and open into the femoral vein, usually a little below the point where it receives the deep femoral vein.

Variations.—The portion of the femoral vein above the entrance of the deep femoral is sometimes termed the common femoral vein and the rest of it the superficial femoral, the common femoral being formed by the union of the superficial and deep veins.

Occasionally the vein lies anterior to the artery throughout a considerable portion of its course, and it may be double to a greater or less extent, the two veins in such cases either lying posterior to the artery or one on either side of it.

It occasionally passes up the leg behind the adductor magnus, passing through the muscle where it is normally perforated by one of the perforating veins, this arrangement being apparently due to the enlargement of a connection with the deep femoral and of the anastomosis between the perforating veins. In such cases the femoral artery is accompanied by one or two small stems, perhaps representing the venæ comites, and in those cases in which the popliteal vein passes up the back of the thigh (page 911) the femoral is also greatly reduced in size.

THE SUPERFICIAL VEINS.

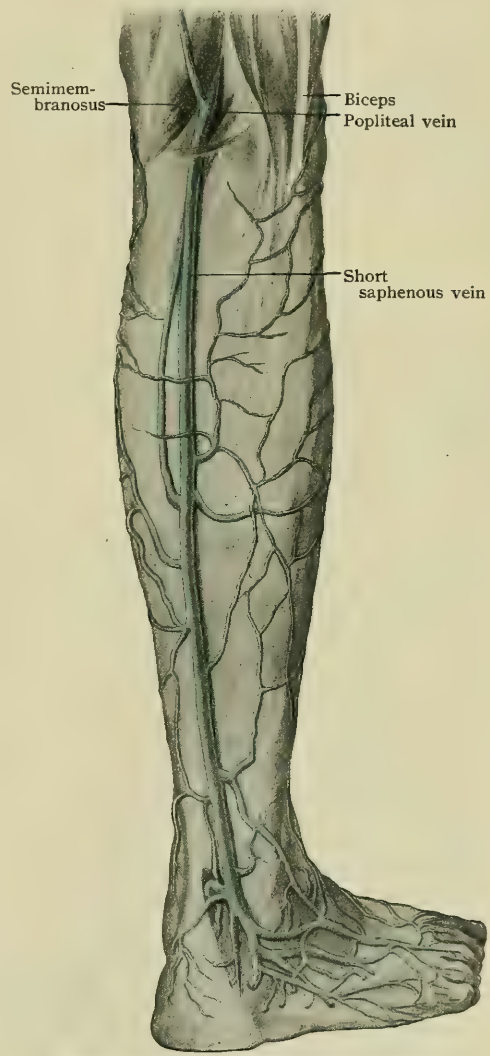
The Superficial Veins of the Foot.

It has already been pointed out (page 910) that the dorsal and plantar digital veins may be grouped either with the superficial or deep veins of the foot, since they communicate extensively with both sets. The superficial connections of the plantar digitals are with an **arcus venosus plantaris cutaneus** which runs across the foot at the bases of the toes and, bending upward over the edges of the foot, communicates with the dorsal veins. Posteriorly to this arch is a subcutaneous net-work (**rete venosum**

plantare cutaneum) which is especially close in the fatty pad beneath the heel, but more open towards the bases of the toes. This net-work makes numerous connections with the deep plantar veins, and to a great extent is drained by superficial emissaries which pass upward over the borders of the foot and open into the superficial dorsal veins. These emissaries are larger on the inner than on the outer side of the foot, and they all have a somewhat backward as well as an upward direction, those from the most posterior portions of the plexus passing directly backward and upward over the tuberosity of the heel. Anteriorly the more central portions of the net-work drain into the superficial plantar arch and communicate through this with the dorsal veins.

The dorsal digital veins form by their union in pairs the **common digital veins** (**vv. digitales communes pedis**), which correspond in position to the dorsal interosseous veins, except that they are subcutaneous. Posteriorly these veins anastomose to from a more or less regular **dorsal subcutaneous arch** (**arcus venosus dorsalis pedis**), which extends across the dorsal portions of the metatarsal bones, being convex distally and increasing in size from the outer to the inner border of the foot. Proximally to this arch there is an irregular net-work of veins (**rete venosum dorsale pedis**) which makes numerous connections with the deep veins and passes proximally into the net-work of the anterior surface of the crus. Towards the borders of the foot, and forming the lateral and medial boundaries of the net-work, a more or less distinct longitudinal **marginal vein** can be seen on each side (**vv. marginales lateralis et medialis**), and it is into these that the superficial emissaries from the plantar net-work open from below. The internal marginal vein is somewhat larger than the external and joins the dorsal arch to form the long saphenous vein, while the external is the principal origin of the short saphenous.

FIG. 770.



Superficial veins on dorsum of right foot and posterior surface of leg.

THE SHORT SAPHENOUS VEIN.

The short or external saphenous vein (**v. saphena parva**) (Fig. 770) is the superficial vein of the back of the crus. It begins behind the external malleolus at the upward continuation of the external marginal vein of the foot. It lies at first upon the outer border of the tendo Achillis, but later takes a more median position and ascends the posterior surface of the leg almost in the median line. At about the middle of the leg it perforates the crural fascia and continues its upward course in the groove between the two heads of the gastrocnemius, and, entering the popliteal space, terminates by dividing into two branches, one of which opens into the posterior surface of the popliteal vein about on a level with the origins of the gastrocnemius, while the other passes farther upward to communicate with the beginning of the deep femoral vein.

The short saphenous vein possesses from nine to ten valves in its course up the leg. In its lower part it accompanies the external or short saphenous nerve, which lies beneath (*i.e.*, anterior to) it, and above it accompanies a branch of the small sciatic nerve.

Tributaries.—The short saphenous vein drains the outer border of the foot and the whole of the posterior superficial portion of the crus. Near its origin it receives the posterior emissaries from the superficial plantar net-work, and throughout its course up the crus it receives numerous branches from the superficial net-work of the posterior surface of that portion of the leg, and through this net-work makes communications with the long saphenous vein. The terminal branch which communicates with the deep femoral vein receives a stem known as the v. **femoropoplitea**, which runs downward upon the back of the thigh, superficially, receiving branches from the posterior superficial net-work of the thigh and communicating above with the sciatic and gluteal veins.

Variations.—The short saphenous vein occasionally opens into the long saphenous by the enlargement of one of the anastomoses between the two veins, only a small vessel representing its communication with the popliteal. It has been observed to continue up the thigh without or with but a small communication with the popliteal and deep femoral veins, and, entering the pelvis with the great sciatic nerve, to open into the internal iliac vein. In such cases its femoral portion probably represents the original femoral portion of the sciatic vein, and has the same significance as the prolongation of the popliteal up the thigh of which mention has already been made (page 911).

The Long Saphenous Vein.

The long or internal saphenous vein (**v. saphena magna**) (Fig. 771) has its origin in the junction of the inner end of the dorsal arch of the foot with the inner marginal vein. It passes upward in front of the inner malleolus and then in the groove between the medial border of the tibia and the inner border of the gastrocnemius muscle. As it approaches the knee-joint it bends slightly backward to pass behind the internal condyle of the femur, and then continues up the thigh in an almost direct course to the fossa ovalis, where it pierces the cribriform fascia and opens into the femoral vein.

It is subcutaneous throughout its entire course and possesses from twelve to eighteen valves, some of which, especially in old individuals, are apt to be insufficient. Throughout its course up the crus it accompanies the long saphenous nerve, and in the thigh it lies at first along the line of the outer (anterior) edge of the sartorius, but later crosses that muscle obliquely so as to lie internal to it above.

Tributaries.—At its origin the long saphenous vein receives some of the more posterior internal emissaries of the plantar net-work, and in its course up the crus it receives the blood from all those portions of the superficial crural net-work which do not communicate with the short saphenous. In the thigh it is the collecting stem for all the superficial veins, those from the posterior surface frequently uniting to form an **accessory saphenous vein** (**v. saphena accessoria**), while those from the anterior surface may form an **external superficial femoral vein** (Fig. 771).

Throughout its entire course it makes numerous connections with the deep veins, with the anterior tibial by some five or six branches (*vv. sapheno-tibiales anteriores*), with the posterior tibial by usually three (*vv. sapheno-tibiales posteriores*), and with the femoral or one of its tributaries by usually a single one. Various communications with the small saphenous also occur.

In addition to these various connections, the long saphenous receives, just before its entrance into the femoral, a number of vessels which accompany some of the superficial branches of the femoral artery. They are by no means constant tributaries of the saphenous, but frequently pass through the cribriform fascia to open directly into the femoral vein.

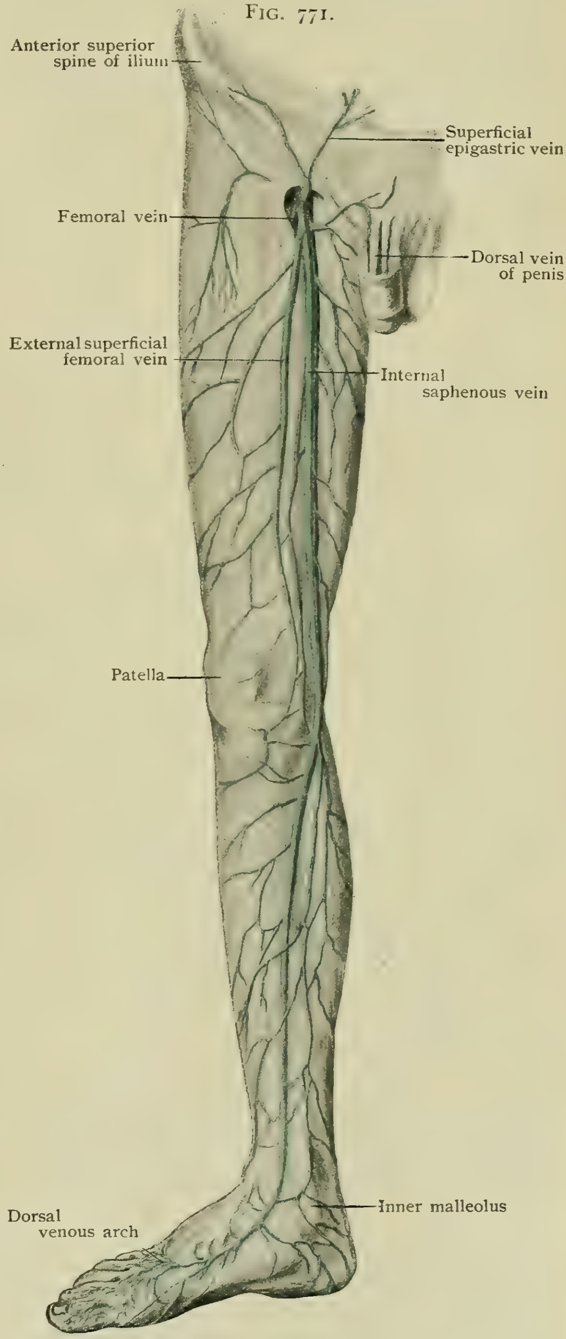
1. **The External Pudic Veins.**—The external pudic veins (**vv. pudendae externae**) are, like the corresponding arteries, two in number, one superficial and one deep. They have their origin in the external genitals, receiving numerous veins from the anterior surface of the scrotum (**vv. scrotales anteriores**) or the anterior portions of the labia majora (**vv. labiales anteriores**). They also receive a

single or paired vein which runs along the dorsal surface of the penis or clitoris immediately beneath the integment (**v. dorsalis penis (clitoridis) subcutanea**), and at the symphysis pubis bends laterally to join the external pudics.

2. **The Superficial Circumflex Iliac Vein.** — The superficial circumflex iliac vein (**v. circumflexa ilium superficialis**) accompanies the artery of the same name, receiving subcutaneous branches from the lower lateral portions of the abdomen and from the anterior hip region. It frequently unites with the superficial epigastric vein before opening into the saphenous.

3. **The Superficial Epigastric Vein.**—The superficial epigastric vein (**v. epigastrica superficialis**) takes its origin from the subcutaneous veins of the lower part of the anterior abdominal wall as high as a little above the umbilicus. It is joined at a varying level by the *thoraco-epigastric vein* (Fig. 775), which opens above into the axillary vein, and is occasionally prolonged downward to open independently into the long saphenous.

Fig. 771.



Superficial veins of right lower limb; internal aspect.

Variations.—The long saphenous vein may perforate the fascia lata some distance below the fossa ovalis. It is not infrequently replaced in the crural portion of its course by a net-work of veins in which no special main stem can be recognized, and in the thigh it is occasionally double.

Practical Considerations.—The Iliac Veins and the Veins of the Lower Extremity.

The **common iliac veins** illustrate the rule (Owen) that below the diaphragm the veins of the trunk are on a plane posterior to the arteries (except the renal) and incline generally to the venous—the right—side. Thus the left common iliac is always on the inner (right) side of the corresponding artery and ultimately crosses the right artery, on a posterior plane. The right vein begins slightly to the inner side of the right artery, which it crosses—on a posterior plane—to reach the right side of the fifth lumbar vertebra. These relations are important in operations on the common iliac arteries (page 808).

The **internal iliac veins** may become involved in infections of any of the numerous plexuses from which their tributaries arise. Thus, puerperal metritis may not only lead to pelvic cellulitis (page 2014), but may set up a thrombo-phlebitis in the intra-uterine veins which, spreading to the internal and common iliac veins, will obstruct the venous current from the whole lower extremity, bringing about a wide-spread œdema, with aching and tenderness (phlegmasia alba dolens, milk leg). Similar conditions sometimes follow septic infection of the prostatic vesical and hemorrhoidal plexuses. The practical relations of these venous channels have been described in connection with the prostate, bladder, and rectum. The branches of the internal iliac vein aid indirectly in supporting the pelvic viscera. They are apt to be varicose in the aged, especially in females. They supply the blood in cases of pelvic hæmatocele.

The **external iliac vein** is frequently involved in femoral phlebitis, the continuity of direction and calibre between it and the femoral being practically unbroken.

The **femoral vein** is not infrequently the subject of thrombo-phlebitis, descending, as a result of some form of pelvic infection (*vide supra*), or ascending, following septic infection of the soft parts or bones of the lower extremity; or occasionally directly caused by contusion of the vessel just below the groin, or by its bruising during forced flexion of the thigh. Femoral phlebitis is not uncommonly a sequel of enteric fever and of other exhausting diseases, and is a familiar post-operative complication of operations for the removal of the appendix, the uterus, the tubes and ovaries, and other abdomino-pelvic procedures, even when apparently unattended by infection. The predisposing causes are thought to be the relative immobility of the patient and the consequent sluggishness of the circulation, especially in the lower extremities, the dependent position of the limb in bed, and the altered constitution of the blood (in the case of fever); the exciting cause is probably a very slight degree of infection. Pain and œdema follow, but such cases almost always do well. On account of its nearness to the artery, both vessels are often wounded at the same time, with the resulting formation—if the communication between them is direct—of an aneurismal varix; or if it is indirect—an aneurismal sac intervening—of a varicose aneurism. Wounds requiring ligation and sudden occlusion of the vein from any cause are dangerous from the risk of development of moist gangrene. Lateral suture of wounds in this vein has been successfully employed in a number of instances. The femoral vein is not infrequently involved in ulcerative malignant or phagedenic processes implicating the skin of the groin and upper thigh, or the inguinal lymphatic nodes.

After ligation, the collateral circulation is established between the veins of the buttocks and the internal circumflex veins, and between the veins of the pelvis and the external pudic veins.

The practical relations of the femoral vein to femoral hernia have been described (page 1773).

The **popliteal vein**, together with the artery (which is closer to the bone, and therefore more easily compressed or torn), has been lacerated in supracondyloid fracture of the femur. It has been so compressed by a popliteal aneurism as to cause thrombosis and enormous distention of the veins and of the leg. Owing to the unyielding character of the boundaries of the ham, it may also be sufficiently compressed by inflammatory exudates, by abscess, or by enlarged bursæ, to cause swelling and œdema of the foot and leg The vein is so exceptionally thick-walled that in spite of its more superficial position it is never ruptured alone, but only when the force is sufficient to tear the artery also. The involvement of both may be favored by the fact that the two vessels are so closely united that it is difficult to separate them, and this also favors the occasional production of aneurismal varix or varicose aneurism after stab-wounds. This close connection makes the denudation of the artery difficult in the operation for its ligation.

The **veins of the leg** are, with the possible exception of the veins of the pampiniform and hemorrhoidal plexuses, more often the subject of varicosity than any other veins of the body. This is due to (1) the high blood-pressure in these veins, resulting from (*a*) the erect posture of the human species and the consequent

vertical position of these veins ; (*b*) the length of the column of blood they carry, extending, in the case of the long saphenous vein, from its beginning at the ankle to the upper orifice of the inferior vena cava ; (*c*) in many cases to compression above, as from abdominal or pelvic growths, or the gravid uterus, or from garters. (2) In the superficial veins the frequency of varicosity is also due to the lack of adequate external support to their thin and distensible walls, the saphenous veins, for example, lying outside of the deep fascia in loose connective tissue. (3) To the increased resistance that must be overcome at the points where the deep and superficial vessels communicate, and where in many cases the varicosity seems to begin. At such points the upward current of blood has to overcome—and the walls of the veins to support—not only the downward pressure of the vertical column of blood in the vessels above it, but also the resistance of the blood-stream driven out of the deep vein by the contracting muscles between which it lies, and entering the superficial vein at a right angle. The valve next below this point of entrance prevents the relief that might be obtained from temporary distention of a long lower section of the vein and limits these forces to a circumscribed area, which yields and becomes varicose.

The venous plexus between the two layers of the muscles of the calf is often the seat of varices of great size. The six chief veins which pass from the soleus muscle alone to enter into the posterior tibial and peroneal trunks have a united diameter of not less than one inch (Treves).

The fact that each of the saphenous veins is accompanied by a sensory nerve accounts for the aches and pains associated with varicosity.

THE PORTAL SYSTEM.

The portal system is composed of all the veins which have their origin in the walls of the digestive tract below the diaphragm (with the exception of those of the lower part of the rectum) and includes also the veins which return the blood from the pancreas, spleen, and gall-bladder. It presents a marked peculiarity in that the system begins and ends in capillaries, the blood which it contains having entered its constituent veins from the capillaries of the intestine, stomach, and the other organs mentioned above, and passing thence to the liver, where it traverses another set of capillaries, by which it reaches the hepatic veins and so the heart. Coming as it does principally from the intestine, the portal blood is more or less laden with nutritive material, which has been digested and absorbed through the intestinal walls, but is not yet in a condition, so far as some of its constituents are concerned, suitable for assimilation by the tissues. To undergo the changes necessary for its conversion into assimilable material it is carried by the portal vein to the liver, and as it passes through the capillaries of that organ it undergoes the necessary modifications.

In other words, the portal vein stands in a somewhat similar relation to the liver that the pulmonary vein does to the lungs. Its purpose is not to convey material to the organ for its nutrition, that being accomplished by the hepatic arteries for the liver just as it is accomplished by the bronchial arteries for the lungs, but to carry to the liver crude material upon which the organ may act, elaborating it and returning it, as required, to the circulation in a purified and assimilable condition.

The inclusion of the veins of the spleen, gall-bladder, and pancreas, or even of those of the rectum, in the portal system is to be explained on the ground of topographic relationship rather than on the basis indicated above.

The main stem of the portal system will first be described and then its tributaries in succession.

The Portal Vein.

The portal vein (**v. portae**) (Figs. 772, 774) is formed behind the head of the pancreas by the union of the superior mesenteric and splenic veins, the latter receiving the inferior mesenteric vein shortly before its union with the superior mesenteric. The two veins unite almost at a right angle, and from their point of union the portal vein passes obliquely upward and to the right, along the free edge of the lesser omentum, towards the transverse fissure of the liver. There it divides into two trunks, of which the right is the larger and shorter and quickly bifurcates into an anterior and a posterior branch. It is distributed to the whole of the right

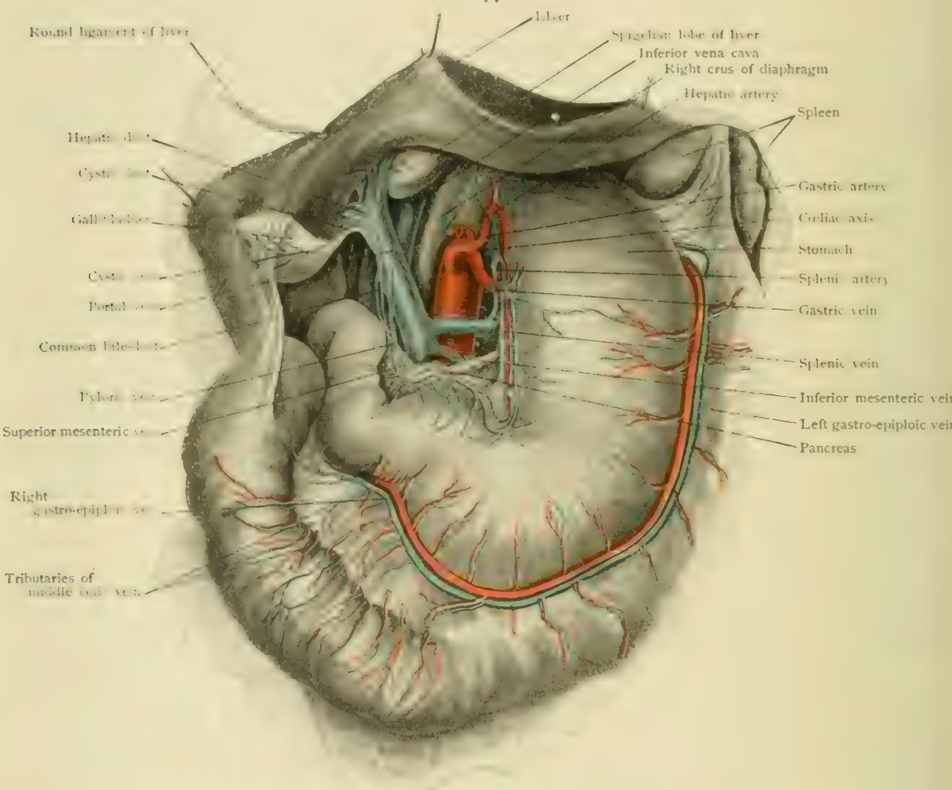
lobe of the liver and to the greater part of the Spigelian and quadrate lobes, the remainder of these lobes and the left lobe receiving branches from the left trunk.

The trunks of the vein or their branches enter the substance of the liver and divide in a more or less distinctly dichotomous manner to form *interlobular veins*, which, as their name indicates, occupy a position between the lobules of the organ, and give off capillaries which traverse the lobule and empty into the intralobular veins, the origins of the hepatic veins.

The portal vein measures about 8 cm. (3¼ in.) in length and has a diameter of from 1.5 to 2 cm. Its walls, especially in its upper portion, contain a considerable quantity of muscle-tissue and it is destitute of valves.

Relations.—At its origin the portal vein lies behind the head of the pancreas and to the left of the vena cava inferior. As it ascends it comes to lie at first behind

FIG. 772.



Portal vein and its tributaries; liver has been pulled upward.

the first portion of the duodenum and then between the two layers of the lesser omentum. In this latter portion of its course it is associated with the hepatic artery and the common bile-duct, both of which lie anterior to it, the artery to the left and the duct to the right. It enters the transverse fissure towards its right extremity, hence the shortness of the right trunk compared with the left, and its trunks have in front of them the branches of the hepatic artery, the hepatic ducts lying anterior to these.

Tributaries.—The tributaries of the portal vein are: (1) the *superior mesenteric*, (2) the *splenic*, (3) the *inferior mesenteric*, (4) the *gastric*, (5) the *pyloric*, and (6) the *cystic veins*. In addition to these principal tributaries, the portal vein, or its branches within the liver, also receives a number of small veins which have their origin in the falciform ligament of the liver and in the lesser omentum, and, furthermore, it receives at the transverse fissure (7) some *parumbilical veins* which ascend the anterior abdominal wall along with the round ligament.

1. **The Superior Mesenteric Vein.**—The superior mesenteric vein (v. mesenterica superior) (Fig. 773) accompanies the artery of the same name, lying upon its right side. It has its beginning somewhere in the neighborhood of the terminal portion of the ileum and ascends in the line of attachment of the mesentery. Above, it passes over the third portion of the duodenum and then between that portion of the intestine and the lower border of the pancreas, uniting behind the head of the pancreas with the splenic vein to form the portal vein. It possesses no valves.

Tributaries.—The tributaries of the superior mesenteric vein correspond with the branches of the corresponding artery, except that it receives in addition the pancreatico-duodenal and right gastro-epiploic veins which accompany the similarly named branches of the hepatic artery.

(*a*) The **veins of the small intestine** (vv. intestinales) have their origin in the walls of the small intestine from the last portion of the duodenum to within a short distance of the ileo-cæcal valve. Their arrangement is essentially similar to that of the arteries of the small intestine, the numerous small branches which emerge from the intestine being united by transverse anastomoses, as a rule more numerous than those of the arteries, and forming one or more series of venous arcades lying between the two layers of the mesentery. From these arcades branches arise which pass towards the superior mesenteric vein, gradually uniting to form about twenty stems which open independently into the superior mesenteric. The branches of origin of the intestinal veins. just after they emerge from the intestine are provided with valves in the child, but they usually degenerate more or less completely before adult life.

(*b*) The **ileo-colic vein** (v. ileocolica) arises at the junction of the ileum and cæcum by the union of a cæcal and an ileal branch, the latter of which anastomoses with the origin of the superior mesenteric. The cæcal branch receives an appendicular vein from the appendix vermiformis, and the main stem passes upward between the two layers of the mesentery to open into the superior mesenteric just before it passes over the duodenum.

(*c*) The **right colic veins** (vv. colicae dextrae) originate in the walls of the ascending colon and are two or three in number. They anastomose by transverse branches with the ileo-colic and middle colic veins and pass almost horizontally medially to open into the superior mesenteric.

(*d*) The **middle colic vein** (v. colica media) emerges from the transverse colon by a number of small branches which anastomose to the right and left with the right and left colic veins, and unite to a single stem which opens into the superior mesenteric just before it passes beneath the pancreas.

(*e*) The **right gastro-epiploic vein** (v. gastroepiploica dextra) runs from left to right along the greater curvature of the stomach, communicating directly with the left gastro-epiploic at about the middle of the curvature. It receives tributaries from the lower portions of the anterior and posterior surfaces of the stomach and from the greater omentum, and opens into the superior mesenteric shortly before its union with the splenic. It occasionally receives a pancreatico-duodenal vein, and may unite with the middle colic vein to form a gastro-colic vein instead of opening directly into the superior mesenteric.

(*f*) The **pancreatico-duodenal veins** (vv. pancreaticoduodenales), like the arteries, may be two in number, one of which opens directly into the superior mesenteric and the other into the right gastro-epiploic. Frequently, however, they are broken up into a number of separate vessels arising independently from each of the two viscera concerned, the duodenum (vv. duodenales) and the head of the pancreas (vv. pancreaticae).

2. **The Splenic Vein.**—The splenic vein (v. lienalis) (Fig. 774) is formed by the union of five or six branches which emerge from the hilum of the spleen. It passes almost horizontally to the right below the splenic artery, resting at first upon the upper border of the pancreas, but later coming to lie behind that organ. Behind the head of the pancreas it unites with the superior mesenteric to form the portal vein.

Tributaries.—These correspond with the branches of the artery, and in addition it receives near its termination the inferior mesenteric vein, which for purposes of description will, however, be regarded as independent.

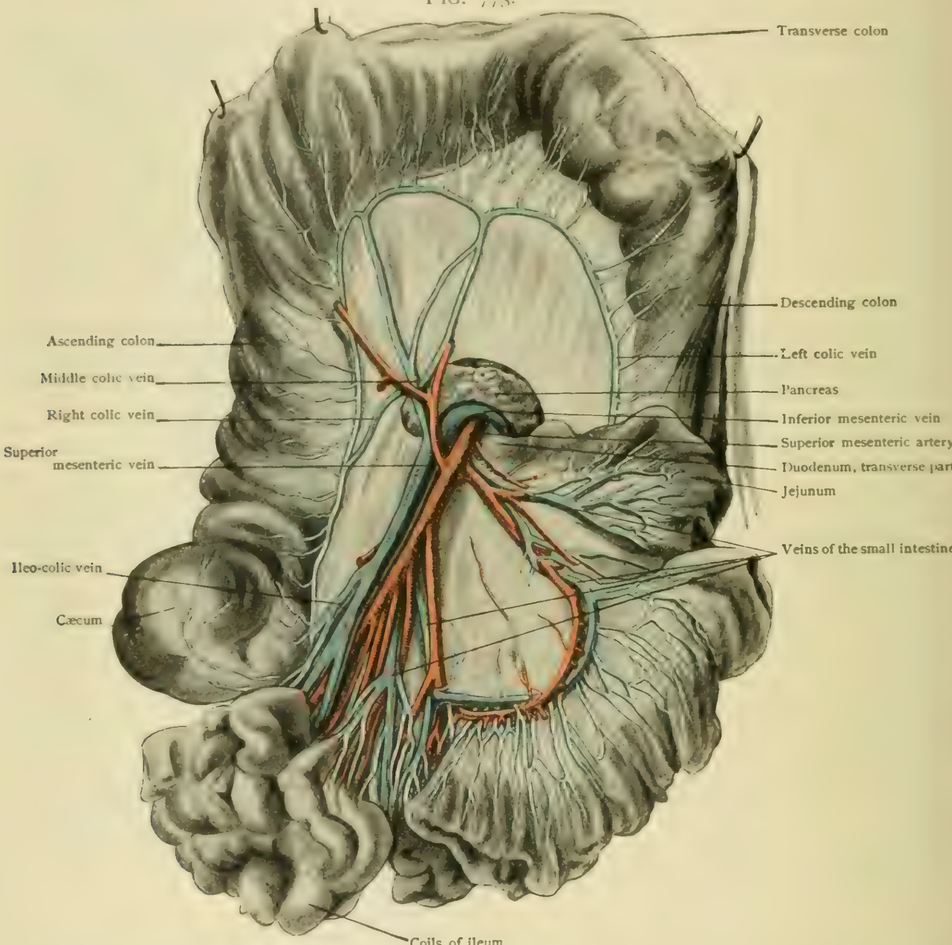
(*a*) The **short gastric veins** (vv. gastricae breves) arise from the fundus of the stomach and pass between the layers of the gastro-splenic omentum to open partly into the splenic vein and partly into its branches of origin as they emerge from the hilum.

(*b*) The **left gastro-epiploic vein** (v. gastroepiploica sinistra) passes from right to left along the greater curvature of the stomach, communicating directly with the right gastro-epiploic about half-way along the curvature. It receives branches from the lower portions of both surfaces of the stomach and from the greater omentum, and opens into the splenic vein near its formation.

(*c*) The **pancreatic veins** (vv. pancreaticae), which may be five or more in number, open into the splenic vein at various points in its passage behind the pancreas.

3. **The Inferior Mesenteric Vein.**—The inferior mesenteric vein (v. **mesenterica inferior**) (Fig. 774) is formed by the junction of the superior hemorrhoidal and sigmoid veins opposite the sigmoid flexure of the colon, and passes upward in company with the corresponding artery. It is continued on, however, beyond the point where the artery arises from the abdominal aorta, lying behind the peritoneum slightly medial to the ascending colon, and, finally, it passes beneath the pancreas

FIG. 773.



Superior mesenteric vein and its tributaries; transverse colon has been pulled upward.

to open usually into the splenic vein not far from its union with the superior mesenteric. Occasionally it opens into the latter vein (Fig. 774) or else equally into both, thus taking a direct part in the formation of the portal vein.

Tributaries.—Its tributaries correspond to the branches of the artery.

(*a*) The **superior hemorrhoidal vein** (**v. haemorrhoidalis superior**) has its origin from the upper part of the hemorrhoidal plexus by several branches, and, passing upward, unites with the sigmoid veins to form the inferior mesenteric. Through the hemorrhoidal plexus it communicates with the middle and inferior hemorrhoidal veins, thus placing the portal and inferior caval systems in communication.

(*b*) The **sigmoid veins** (**vv. sigmoideae**) are variable in number and pass from the sigmoid flexure and the lower portion of the descending colon to the inferior mesenteric, the lowest one uniting with the superior hemorrhoidal to form that vein.

(*c*) The **left colic vein** (v. colica sinistra) has its origin in the walls of the descending colon, anastomosing above with the middle colic and below with the sigmoid veins. It passes medially to open into the upper part of the inferior mesenteric.

4. **The Gastric Vein.**—The gastric vein (**v. coronaria ventriculi**) (Fig. 772) accompanies the gastric artery along the lesser curvature of the stomach. It has its origin at the pyloric end of the stomach, where it anastomoses with the pyloric vein, and passes at first from right to left along the lesser curvature, receiving tributaries from the upper part of both surfaces of the stomach. At the opening of the œsophagus into the stomach it makes connections with the œsophageal veins, and then bends upon itself and passes from left to right behind the posterior wall of the lesser sac of the peritoneum, and terminates either in the portal vein or in the splenic shortly before its union with the superior mesenteric.

The peculiar reflected course of the gastric vein is readily understood if it be remembered that the adult position of the stomach is a secondary one. When first formed the long axis of the stomach is practically vertical, the pyloric end being directed downward, and a vein starting at the pylorus will have a direct ascending course to the portal vein. When the stomach assumes its adult position the course of the vein with reference to the viscus does not alter, and consequently it passes from pylorus to cardia, and must then bend back upon itself to reach the portal vein.

5. **The Pyloric Vein.**—The pyloric vein (v. **pylorica**) (Fig. 772) accompanies the pyloric branch of the hepatic artery. It takes its origin at the pyloric end of the stomach, where it anastomoses with the gastric vein, and passes downward to open into the portal.

6. **The Cystic Vein.**—The cystic vein (**v. cystica**) (Fig. 772) returns the blood from the walls of the gall-bladder and opens usually into the right trunk of the portal vein. It is frequently represented by two separate stems.

7. **The Parumbilical Veins.**—The parumbilical veins (**vv. parumbilicales**) are a number of small veins which have their origin in the anterior abdominal wall in the neighborhood of the umbilicus and pass upward in the fold of peritoneum which contains the round ligament of the liver. They anastomose below with both the superficial and deep epigastric veins and also with small vessels which pass downward alongside of the urachus to empty into the vesical plexus. Above, the majority of them enter the quadrate and left lobes of the liver, but one of them, the **vena supraumbilicalis,** enters the substance of the round ligament at a varying level and opens into the more or less extensive lumen of that structure, which represents the umbilical vein of fœtal life. This lumen appears to persist in the majority of cases, although greatly reduced in size from that of the umbilical vein, and may extend throughout almost the entire length of the round ligament, although perhaps, more usually, it is limited to its upper part, and opens into the right trunk of the portal vein. When the lumen is entirely obliterated it is possible that the supraumbilical vein, which has also been termed the *accessory portal vein*, may open directly into the portal vein.

Collateral Circulation of the Portal Vein.—Considering the fact that the portal vein terminates in capillaries in the substance of the liver, it is evident that certain pathological conditions, such as cirrhotic changes, which may occur in that organ, will more or less completely interfere with the return of the blood to the heart from the intestine, spleen, and pancreas, by producing an obliteration of the capillaries. The possibilities of a collateral circulation are therefore important, and a number of routes occur by which, under stress, the blood of the portal venous system may pass around the liver and reach the heart through one of the other systems. The functional capabilities of these various routes are furthered by the fact that none of the tributaries of the portal vein possess valves except in their finer branches, and the blood can therefore flow in them in a reverse direction if necessary. The principal collateral routes are as follows:

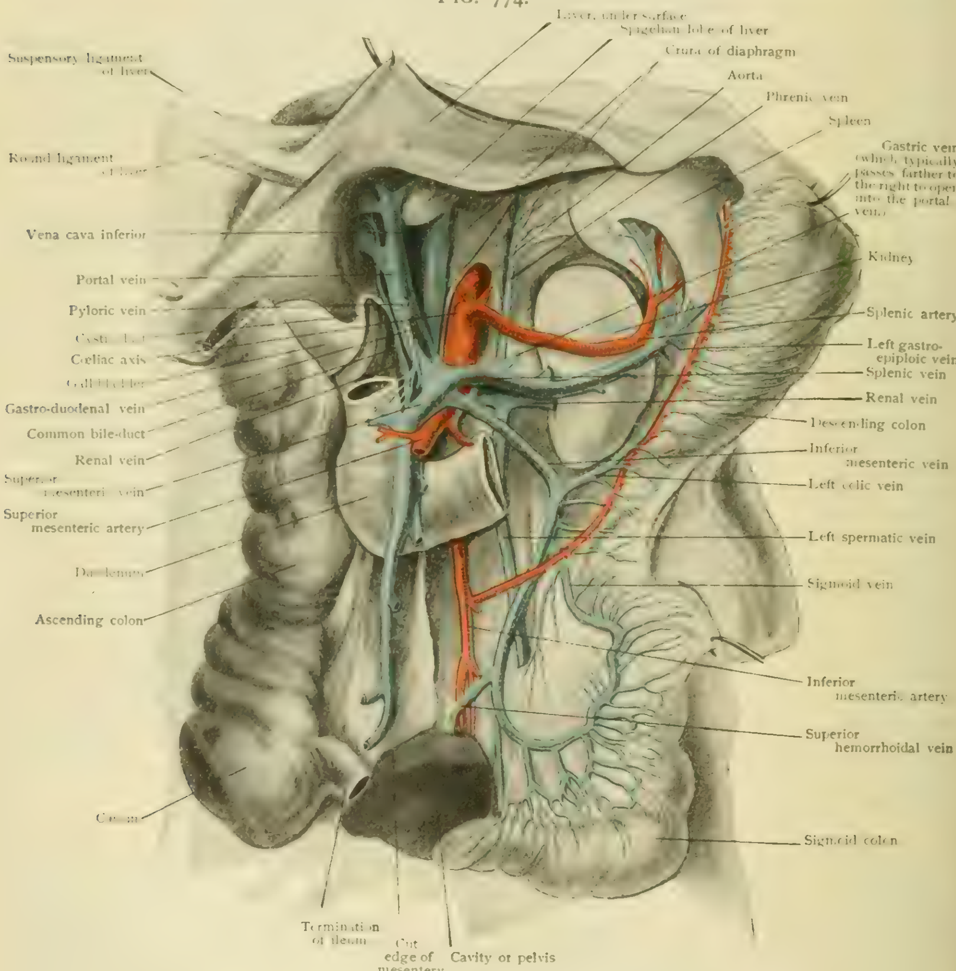
1. *Through the gastric vein* the blood may pass to the œsophageal veins and thence to the azygos and hemiazygos veins. When this route is functional the œsophageal veins become enlarged and frequently varicose, forming contorted elevations upon the surface of the œsophagus.

2. *Through the superior hemorrhoidal veins* connections are made by way of the hemorrhoidal plexus with the hemorrhoidal branches of the internal iliac. These connections seem, however, to be less frequently functional than either the cardiac or parumbilical routes.

3. *Through the umbilical and supraumbilical veins* to the superficial or deep epigastrics and so to the external iliac veins. It is interesting to note that in cases where this route is functional the enlargement of the superficial epigastric veins is usually accompanied by a development of varicosities upon them, while this is not the case with the deep epigastrics. An explanation of this difference has been found in the fact that the deep veins, before opening into the external iliac, bend slightly backward, so that their orifices are directed in the same way as the flow of blood in the larger stem, whereas the superficial epigastrics open from above into the long saphenous veins, their orifices being opposed, therefore, to the flow of blood in the saphenous, —a condition which naturally predisposes towards stasis of the blood in the epigastrics and, it may be remarked, also of that in the saphenous.

These are the principal routes, but it must be noted that anastomoses also exist between the portal system and the phrenic veins by means of the small veins which descend towards the

FIG. 774.



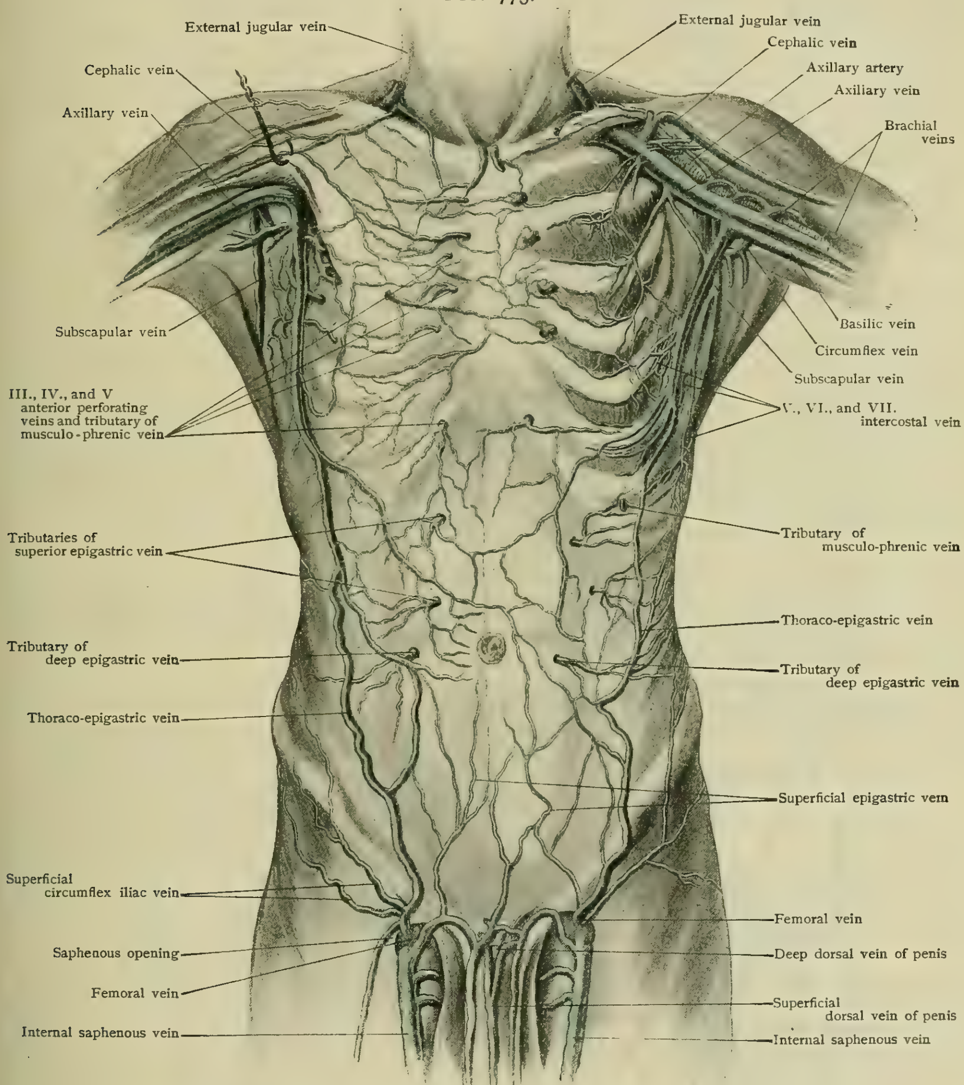
Inferior mesenteric and splenic veins and tributaries of portal vein; stomach and transverse colon have been removed and liver pulled upward.

liver in the falciform ligament, and communications with the inferior caval system also occur by means of retroperitoneal anastomoses between the peritoneal and mesenteric veins, both of which are quite small. These communications are known as the *veins of Retzius*.

Finally, it may be mentioned that anomalous and therefore inconstant communications of the portal branches with those of other systems have been observed. Thus the gastric, the short gastrics, or the pyloric vein may anastomose with the phrenics; the splenic or the left gastro-epiploic with the renals; the right or left colic with the branches from the fatty capsule of the corresponding kidney; and the duodenal branches may open into the inferior vena cava.

Practical Considerations.—The portal system may be obstructed by (*a*) tumors or swellings involving the liver itself, as carcinoma, hydatids, or abscess; (*b*) enlargement of the gall-bladder from new growth or from concretions; (*c*) tumors of contiguous structures, as disease of lymph-nodes in the portal fissure or between the layers of the lesser omentum, or carcinoma of the head of the pancreas; (*d*) disease of the liver tissue, especially cirrhosis (chronic interstitial hepatitis) in which the interlobular veins are compressed by the contraction of the connective

FIG. 775.



Superficial veins of anterior body-wall; pectoralis and external intercostal muscles (of fifth to seventh intercostal spaces) on left side have been removed.

tissue in the spaces between the lobules; (*e*) valvular disease of the heart leading to backward pressure through the cava and hepatic and intralobular veins which finally reaches the terminal capillaries of the portal vein and then the interlobular veins and the entire portal system, resulting in some cases in the so-called nutmeg liver (cyanotic atrophy). The consequences of portal obstruction are various, but may, as a rule, easily be understood by referring each symptom to its anatomical basis in

obstruction of one or the other of the venous tributaries. The chief results are: (1) Enlargement of the liver itself, at first congestive, later from hyperplasia. Diminution in the quantity of bile or alteration in its character may cause constipation and indigestion; or escape of its coloring matter and its absorption by the hepatic veins may give rise to jaundice. (2) From congestion of the gastric and intestinal mucosa (through the superior and inferior mesenteric, splenic, and gastric tributaries) there may develop indigestion, flatulence, eructations, and vomiting, often bloody; serous exudation into the bowel—intestinal indigestion, and diarrhœa, sometimes with black stools from decomposed blood—or into the general peritoneal cavity—ascites; enlargement and tenderness of the spleen; hemorrhoids (from the communication between the middle and inferior hemorrhoidal veins—systemic—and the superior hemorrhoidal vein—portal); varicosities in the lower extremities, possibly from the same communication between the caval and portal systems, but oftener from the direct interference by an enlarged liver with the current in the inferior cava.

Septic inflammation of the liver may reach that organ through any of the portal tributaries. It is not uncommonly the result of infection originating during a dysenteric attack. Cancer may also reach the liver by venous channels, usually by the gastric or hemorrhoidal tributaries.

As the number of extraperitoneal anastomoses between the branches of the parietal vessels (lower intercostal, phrenic, lumbar, ilio-lumbar, epigastric and circumflex iliac) and branches of vessels that supply viscera without a complete peritoneal covering (liver, kidneys, suprarenals, duodenum, pancreas, ascending and descending colon) are of great importance in case of obstruction to the visceral arterial supply, so the corresponding venous anastomoses are of equal or greater importance in obstruction of the portal vein or of the inferior cava. The occasional connection between a parumbilical vein and the external iliacs—through the epigastrics—may also relieve portal obstruction. The above anastomoses explain the effect of leeches or wet cups or counter-irritation of the surface in congestions or inflammations of the partly extraperitoneal viscera. (Woolsey.)

DEVELOPMENT OF THE VEINS.

The embryonic venous system may be regarded as consisting of three sets of vessels. One of these becomes the pulmonary veins, another gives rise to the portal and umbilical veins, while the third is represented by what are termed the cardinal veins. It is to these last that attention may first be directed.

The Cardinal Veins.—The cardinal veins (Fig. 776) are two longitudinal stems which extend the entire length of the body, one on either side of the median line, receiving throughout their course lateral somatic and visceral branches in more or less perfect segmental succession. From each vein a branch passes medially towards the heart, and the portion of the longitudinal vein anterior to this cross-branch is termed the *anterior cardinal* or *primitive jugular*, while that behind it is known as the *posterior cardinal*. The cross-branch, which is usually described as formed by the union of the anterior and posterior cardinals, is termed the *duct of Cuvier*.

FIG. 776.

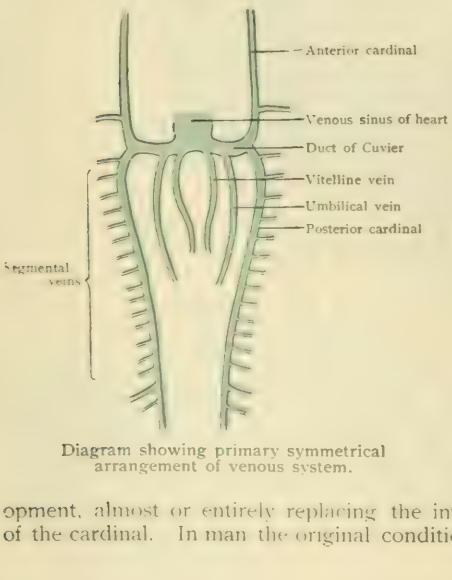


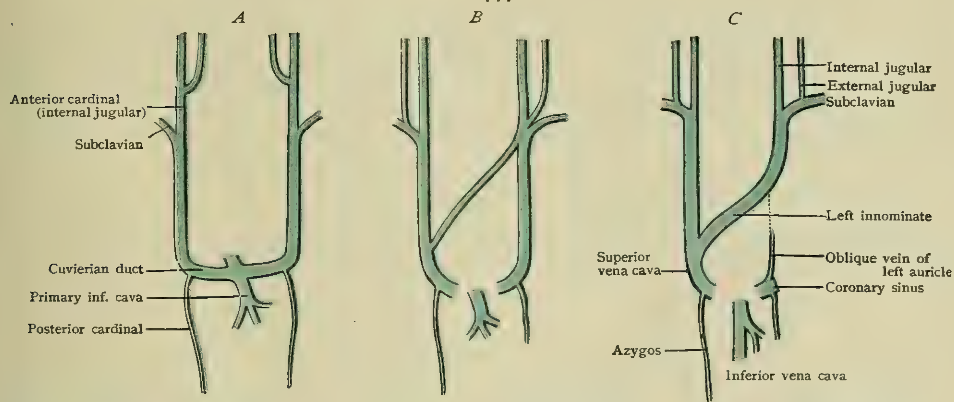
Diagram showing primary symmetrical arrangement of venous system.

The anterior cardinals take their origin from veins which ramify over the surface of the brain and receive at first both the ophthalmic and facial veins. The cerebral veins later condense to form the superior and inferior longitudinal, the straight, and the lateral sinuses, with the last of which the ophthalmic veins unite, their intracranial portions becoming the cavernous and inferior petrosal sinuses. The facial veins, however, sever their connection with the cerebral veins and unite with other superficial veins to form the external jugular—a vessel which in some mammalia reaches a high degree of development, almost or entirely replacing the internal jugular, which represents the main stem of the cardinal. In man the original condition, in which the external jugular is of subordinate

importance, is more nearly retained, but indications of a transference of blood from the intracranial portions of the internal jugular system to the external vessel are to be seen in the emissary veins.

At first each internal jugular opens independently into the right auricle through the corresponding duct of Cuvier (Fig. 777, *A*), but later a communicating branch extending obliquely across from the left to the right vein is developed (Fig. 777, *B*), and thereafter the

FIG. 777.

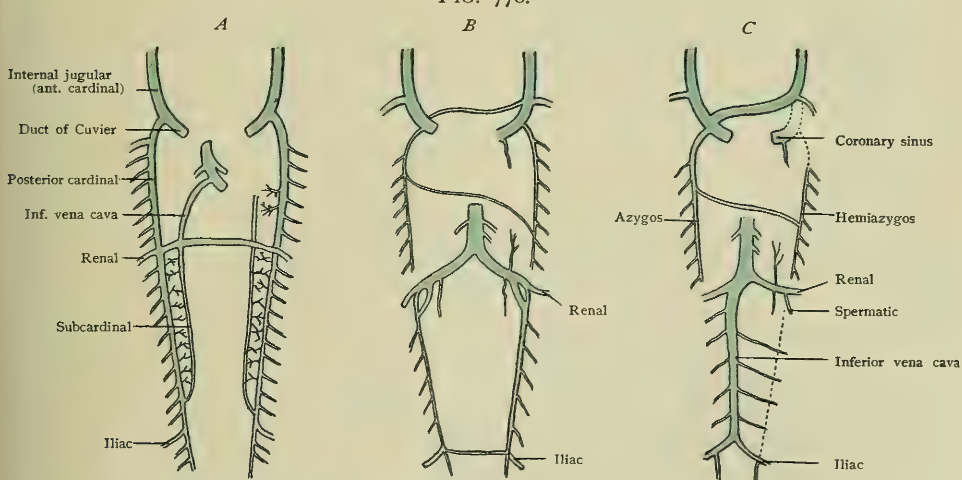


Diagrams illustrating development of superior vena cava; *A*, primary symmetrical arrangement; *B*, establishment of transverse connection; *C*, atrophy on left side and persistence on right side of superior vena cava.

lower portion of the left vein degenerates until it is represented only by the small oblique vein of the left auricle, opening into the coronary sinus, which is the persisting left ductus Cuvieri (Fig. 777, *C*). The oblique connecting branch becomes the left innominate vein of adult anatomy, and the portion of the right anterior cardinal below the point where it is joined by the innominate, together with the right ductus Cuvieri, becomes the superior vena cava.

The Inferior Vena Cava.—The posterior cardinals persist in part as the azygos veins, but their history is so intimately associated with that of the inferior vena cava that an account of the development of the latter may first be presented. In the early stages of development the only portion of the inferior vena cava which exists is the portion which intervenes between the entrance of the hepatic veins and the right auricle, this portion representing the terminal part of the ductus

FIG. 778.



Diagrams illustrating developmental changes leading to formation of inferior caval and azygos veins.

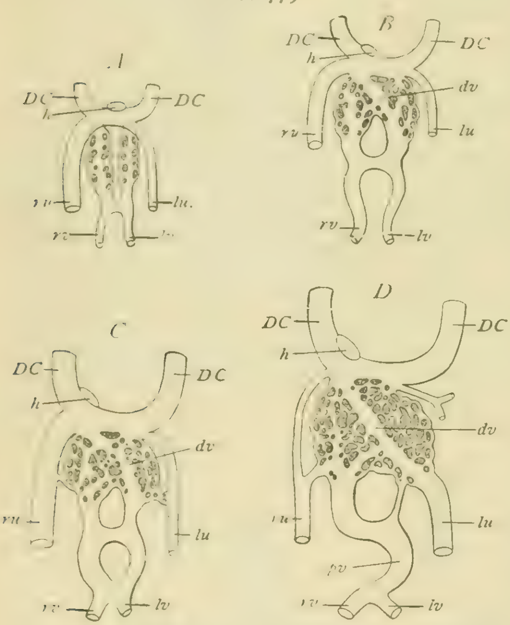
venosus (page 705). Branches which pass to the posterior cardinal veins from the mesentery anastomose longitudinally to form on each side of the body a venous stem which has a course parallel to that of the cardinals, with which it unites below (Fig. 778, *A*). This is the *subcardinal vein*, the two vessels of opposite sides of the body being united with one another and with the cardinals by a strong cross-branch which joins the cardinals opposite the point of entrance into

those of the renal veins. The portion of the right subcardinal which lies anterior to the cross-branch then enlarges and unites with the existing portion of the inferior vena cava, and the lower portion of the right cardinal, together with the portion of the cross-branch which intervenes between it and the right subcardinal, also enlarges, and these three elements eventually come into line with one another and with the terminal portion of the ductus venosus to form the inferior vena cava.

The lower portions of both subcardinals now degenerate, and the upper portion of the left vein, diminishing in size, becomes the left suprarenal vein. A cross-branch forms between the two posterior cardinals at the level of the common iliac veins, and the lower part of the left cardinal then disappears (Fig. 778, *C*), a small portion below the original renal cross-branch alone persisting to form the terminal part of the left spermatic (ovarian) vein, which thus comes to open into the left renal vein, since the terminal portion of that vessel represents the original renal cross-branch. As a result of this degeneration the left common iliac vein comes to open into the lower part of the right posterior cardinal by way of the iliac cross-branch.

The Azygos Veins.—While these changes have been taking place the anterior portions of the posterior cardinals have undergone degeneration immediately anterior to the renal cross-branch (Fig. 778), so that they form independent vessels, receiving the intercostal veins and terminating above in the ductus Cuvieri. They now constitute the azygos veins, and, on the degeneration of the lower part of the left anterior cardinal, the left azygos develops connection with the right by one or two transverse branches and then separates from the coronary sinus, the adult condition of the hemiazygos vein being thus acquired.

FIG. 779.



Diagrams illustrating transformations of vitelline and umbilical veins during development of liver-veins. *DC*, ducts of Cuvier; *h*, heart; *ru*, *lu*, right and left umbilical veins; *rv*, *lv*, right and left vitelline veins; *dv*, ductus venosus; *pv*, portal vein. (*Hochstetter.*)

The Portal Vein.—Passing along the umbilical cord to the body of the embryo are two *vitelline* or *omphalo-mesenteric veins*, which have their origin in the yolk-sac, and the *umbilical vein*, which brings back the blood from the placenta. When it reaches the umbilicus, the umbilical vein divides into two stems which pass upward upon the inner surface of the anterior abdominal wall and unite above with the corresponding vitelline veins to open into the ductus Cuvieri. The vitelline veins pass from the umbilicus to the intestine and ascend along it, receiving tributaries from it; above, they traverse the liver, breaking up into a net-work in its substance, and are then continued on to unite with the umbilicals (Fig. 779, *A*). By the enlargement of certain portions of the hepatic net-work a well-marked venous stem is formed, extending from the point where the left vitelline vein enters the liver to the junction of the common stem formed by the right vitelline and umbilical veins with the duct of Cuvier. This new stem is the *ductus venosus* (Figs. 779, *B* and *C*), and it later forms a connection with the left umbilical vein and becomes the continuation of that vessel as the result of the degeneration of the upper part of the umbilical (*D*).

In the meantime three cross-connections have developed between the two vitelline veins (Fig. 779, *A*, *B*, *C*), two of them passing ventral to the intestine and one dorsal to it, the intestine thus becoming surrounded by two venous rings. The right half of the lower ring and the left half of the upper one now degenerate (*D*), and the persisting portions, which terminate partly in the hepatic net-work and partly in the ductus venosus, become the portal vein. The upper portion of the right umbilical vein has in the meantime made a connection with the upper ring of the vitelline, and the part above the connection then degenerates, the lower part becoming much reduced in size and persisting as a small parumbilical vein in the anterior abdominal wall. This arrangement persists until birth, the placental blood passing by way of the left umbilical vein partly to the ductus venosus and thence by the inferior vena cava to the heart and partly through the hepatic net-work by way of the communication between the left umbilical and vitelline veins. At birth the placental supply of blood is of course cut off, the ductus

venosus degenerates to a solid cord up to the point where the hepatic veins, developed from the hepatic net-work, unite with it. The umbilical vein also degenerates to form the round ligament of the liver, which frequently presents more or less distinct evidences of its original lumen.

The Veins of the Limbs.—The details of the development of the limb veins are not as yet thoroughly known. The superficial veins are the first to form, the basilic vein of the arm and the long saphenous of the leg being the primary vessels and the axillary and subclavian and the iliac veins their respective continuations. The remaining superficial veins and the deep veins are later formations.

The Pulmonary Veins.—The pulmonary veins make their exit from the lungs as four vessels, two belonging to each lung, but as they approach the heart they unite first in pairs and then to form a single trunk which opens into the right auricle. Later a considerable portion of the original veins is taken up into the wall of the auricle, the absorption eventually extending beyond the point of the union of the original veins in pairs, so that in the adult all four veins open independently into the auricle.

THE FŒTAL CIRCULATION.

The primary or **vitelline circulation** of the mammalian embryo, formed by the ramifications of the vitelline arteries and veins over the yolk-sac (umbilical vesicle), must be regarded as an inheritance from ancestors in whom the yolk provided the nutrition for the developing animal. While in birds and reptiles the vitelline veins are important channels for the conveyance of the nutritive materials taken up from the yolk, in mammals in this respect they are of little consequence, thus affording an example of structures that, although no longer useful, recur in the development. The vitelline circulation is soon followed by a second, the **allantoic circulation**, which in man and the higher mammals provides the vessels connecting the fœtus with the placenta—the organ whereby respiration and nutrition are secured to the fœtus during the greater part of its sojourn within the uterus.

The blood is carried from the fœtus to the placenta by the hypogastric arteries and their prolongations, the two *umbilical arteries.* After passing through the vascular tufts of the chorionic villi that constitute the essential structures of the fœtal part of the placenta, the fœtal blood, renewed in oxygen and laden with nutritive material derived from the maternal circulation, is carried by venous tributaries that unite into the single *umbilical vein.* The latter vessel accompanies the umbilical arteries within the umbilical cord as far as the umbilicus, from which point it then passes along the free margin of the crescentic peritoneal fold, the falciform ligament, to the under surface of the liver to join the portal vein and pour its stream of freshly oxygenated blood into the current of venous blood returned from the digestive tract to the liver. For a short time the rapidly growing liver is capable of transmitting all the blood brought to it by the vitelline (later portal) and the umbilical veins, and this blood is returned to the heart after making the circuit of the vessels of the liver. Soon, however, the latter organ can no longer accommodate the entire volume of blood conveyed to it by the portal and umbilical veins, and the necessary relief is afforded by the development of a short vessel, the **ductus venosus,** or *ductus Arantii*, that extends from the portal vein to the inferior vena cava and thus establishes a by-pass for the greater part of the oxygenated blood returned from the placenta. On reaching the inferior cava, this pure blood is mingled with the venous blood being returned from the lower half of the body and the abdominal viscera, the mixed stream so formed being poured into the right auricle. On entering the heart the current is directed by the Eustachian valve towards the **foramen ovale** in the auricular septum and enters the left auricle. After receiving the meagre additions returned by the pulmonary veins from the uninflated lungs, the blood passes through the left auriculo-ventricular opening into the left ventricle. Contraction of this chamber forces the blood into the systemic aorta and thence to all parts of the body.

After traversing the vessels of the head, neck, upper extremities, and thorax, the venous blood from these parts is returned to the heart by the superior vena cava, but on entering the right auricle does not mingle to any extent with the current returned by the inferior cava, but passes through the auriculo-ventricular orifice into the right ventricle. With contraction of the ventricles the blood is propelled into

the pulmonary artery and towards the lungs. Being uninflated these organs can appropriate only a small part of the entire volume of blood brought by the pulmonary artery, hence the necessity of a second by-pass, the **ductus arteriosus**, or *ductus Botalli*, that extends from the beginning of the left pulmonary artery to the adjacent aorta and represents the still pervious distal portion of the last aortic arch on the left side (page 847). By means of the ductus arteriosus, the venous blood returned from the head and upper extremities is poured into the great descending trunk, the aorta, and carried to the abdominal viscera and the lower extremities. On reaching the bifurcation of the common iliac arteries, the blood-stream divides, that part going into the internal iliacs being of much greater importance, so far as the general nutrition of the fœtus is concerned, since it is carried by the continuations of these vessels—the hypogastrics and umbilical arteries—to the placenta, to be once more purified and again returned to the fœtus by the umbilical vein.

FIG. 780.

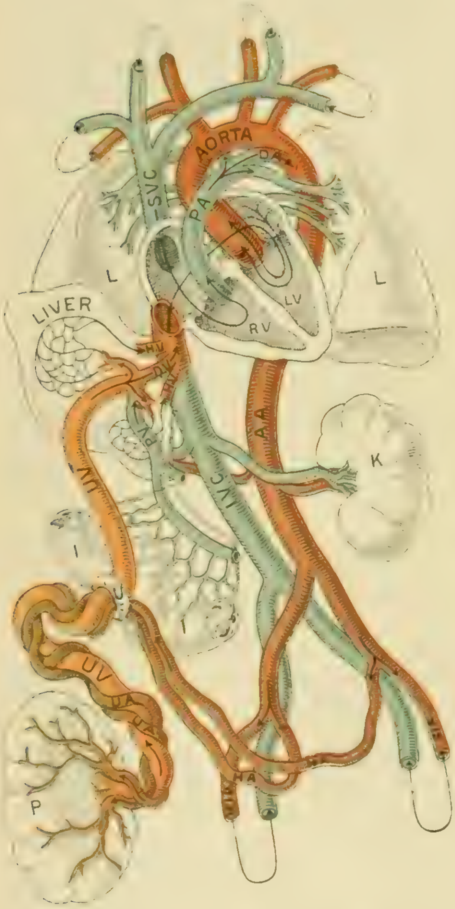


Diagram of fœtal circulation shortly before birth: course of blood is indicated by arrows. P, placenta; UA, UV, umbilical arteries and vein; U, umbilicus; DV, ductus venosus; IVC, inferior vena cava; PV, portal vein; HV, hepatic veins; RV, LV, right and left ventricle; PA, pulmonary artery; DA, ductus arteriosus; SVC, superior vena cava; AA, abdominal aorta; HA, hypogastric arteries (internal iliac); EIA, external iliac arteries; I, intestine; L, lungs; K, kidney.

From the foregoing sketch of the fœtal circulation it is evident that, with the exception of the umbilical vein, no vessel within the fœtus conveys strictly arterial or fully oxygenated blood, since on entering the inferior cava the pure blood is mixed with the venous returning from the lower half of the body. It is further evident that the blood distributed to the head and upper extremities is less contaminated than that passing to the lower half of the body from branches of the aorta given off after junction with the venous stream conveyed by the ductus arteriosus. It may be borne in mind that the umbilical vein and the ductus venosus carry arterial blood and the pulmonary artery and the ductus arteriosus purely venous blood, the aorta distributing mixed. Upon the assumption of the respiratory function at birth, the three anatomical structures peculiar to the fœtal circulation—the ductus venosus, the foramen ovale, and the ductus arteriosus—become useless and soon undergo occlusion and atrophy, the two former ducts being represented by the fibrous cords seen on the posterior surface of the liver and terminal part of the aortic arch respectively. Closure of the foramen ovale proceeds more slowly, a week or more being usually consumed in effecting obliteration of the opening; indeed, in a large proportion of individuals complete closure never occurs (page 695).

THE LYMPHATIC SYSTEM.

THE lymphatic system is a system of vessels which occur abundantly in almost all portions of the body and converge and anastomose to form two or more main trunks, which open into the subclavian veins just before they are joined by the internal jugular. The vessels contain a fluid termed *lymph*, usually colorless, and containing numerous corpuscles known as *lymphocytes*. Since the latter usually come under observation as they circulate within the blood-vessels, the detailed account of the lymphocytes is given in connection with blood-corpuscles (page 684). In those vessels which have their origin in the wall of the small intestine, however, the contained fluid has, especially during digestion, a more or less milky appearance, owing to the lymphocytes being loaded with particles of fat which they have taken up from the intestinal contents. On this account, these vessels are usually spoken of as *lacteals*, although it must be recognized that they are merely portions of the general lymphatic system.

In certain respects the vessels of the system strongly resemble the veins, closely associated with which they take their origin embryologically and into which they finally pour their contents in the adult. They arise from a capillary net-work, their walls have a structure closely resembling that of the veins, they are abundantly supplied with valves, and it may be said that the fluid which they contain flows from the tissues towards the heart. With these similarities there are combined, however, marked differences. One of the most important of these consists in the fact that the capillaries are closed and do not communicate with any centrifugal set of vessels, as the venous capillaries do with the arterial ; and another important difference is to be found in the frequent occurrence upon the lymphatic vessels of characteristic enlargements, the *lymphatic nodes* or so-called *glands* (**lymphoglandulae**), quite different from anything occurring in connection with the veins.

Lymph-Spaces.—Throughout practically all regions of the body spaces of varying size, occupied by a clear, more or less watery fluid, exist, and to these the term *lymph-spaces* has been applied (Fig. 781). It was long believed that they were directly continuous with the lymphatic capillaries, that the latter, indeed, opened out from them, the spaces forming the origins of the capillaries. There is, however, a growing tendency to dispute this view and to regard the lymphatic capillaries as being quite independent of the spaces,—the entire lymphatic system, in fact, being a closed system, except for its communications with the subclavian veins. Since, however, the lymphatic capillaries form net-works in the tissues which bound these spaces, interchange of their contents with those of the capillaries is by no means difficult, the lymphocytes, even, passing on occasion through the walls of the capillaries into the spaces and returning again to the interior of the capillaries.

If a colored fluid be injected into the portal vein it will pass through the walls of the venous capillaries and invade the spaces of the interlobular hepatic connective tissue, and later it will flow away by the hepatic lymph-capillaries. By varying the extent of the injection it will be found that the lymphatic vessels will be injected when the lymph-spaces are completely filled, but will not be when the spaces are only partially injected (Mall), so that it may be concluded that the extravasation from the portal capillaries is primarily into the hepatic lymph-spaces and thence makes its way into the lymph-capillaries.

The spaces vary greatly in size, existing in certain tissues even between the individual cells. They are more evident, however, in the connective tissues, reaching a considerable size in areolar tissue, where they form a continuous net-work, and, since the blood-vessels are usually surrounded by a greater or less amount of connective tissue, lymph-spaces are quite distinct along their courses, forming what are known as the *perivascular lymph-spaces* (Fig. 782). In other regions of the body somewhat extensive spaces occur which have been regarded as belonging to the

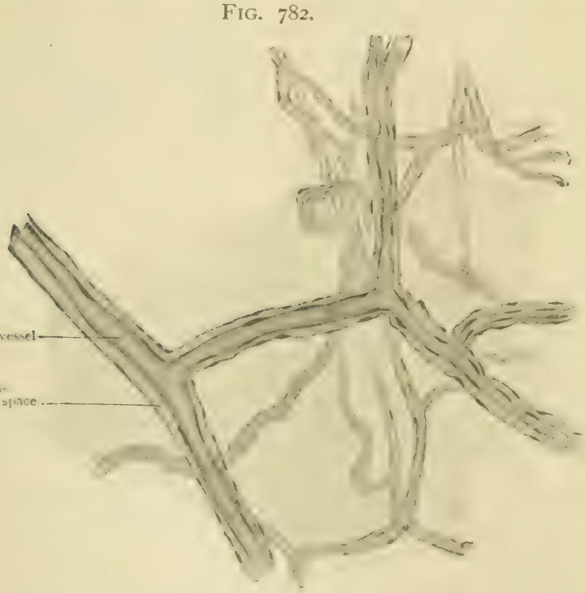
category of lymph-spaces, and among these there may be mentioned the subarachnoid and subdural spaces of the meninges, Tenon's space in the orbit, and even the

FIG. 781.

Portion of central tendon of rabbit's diaphragm, treated with silver nitrate; lymphatic vessels are shown as light irregular tracts; lymph-spaces are seen within stained ground substance. × 120.

spaces occupied by the aqueous and vitreous humors of the eye, as well as the smaller spaces of that organ. So, too, the spaces surrounding that enclosed by the membranous labyrinth of the ear have been regarded as lymph-spaces, as is indicated by their names.

FIG. 782.



Perivascular lymph-spaces surrounding retinal blood-vessels. × 230.

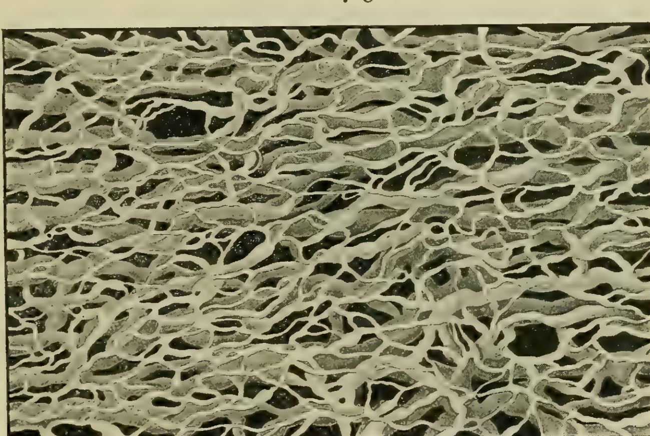
Finally, it may be mentioned that the synovial cavities of the articulations and the greater serous cavities of the body enclosed by the pleura, pericardium, and peritoneum have been regarded as being in direct communication with the lymphatic capillaries; but this view is also in all probability erroneous.

Notwithstanding the independence of these spaces from the lymphatic capillaries, it must be recognized that some of them at least play important rôles from the physiological standpoint, in serving as middle-men between the tissues and the lymphatics, and, furthermore, those of the eyeball, by their communication with neighboring spaces, permit of a

rapid compensation for variations in the intraocular tension. From the anatomical standpoint, however, they are not to be regarded as actually parts of the lymphatic system, and the mention that they here receive is merely a tribute to their historical importance in the problem of the origin of the lymphatic capillaries.

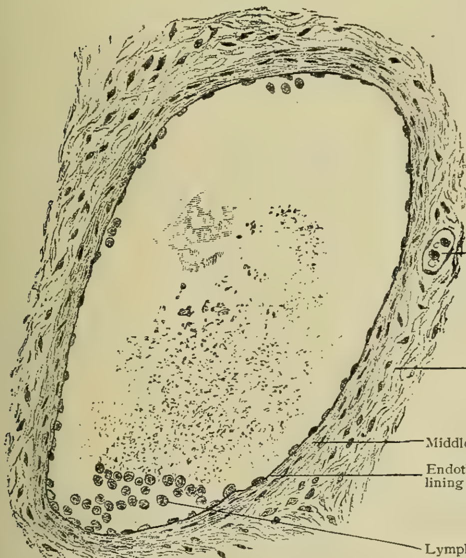
The Capillaries.—The lymphatic capillaries (Fig. 783), which are arranged in the form of net-works of very different degrees of fineness and complexity, closely resemble in structure the blood-capillaries, their walls consisting of a single layer of endothelial plates, which, however, are usually larger and less regularly disposed than those lining the blood-channels. They differ from those of the blood-vascular system not only in their ultimate branches being closed, but also in their general appearance. Thus, they are of much greater calibre, their diameter varying from .030–.060 mm., while that of the blood-capillaries may be as little as .008 mm.; they do not present the regularity of size and gradual increase or diminution of calibre noticeable in the blood-capillaries, but larger and smaller stems are indefinitely interspersed, and spindle-shaped or nodular enlargements may occur at irregular intervals throughout the net-work. And, finally, as a result of these peculiarities, the meshes of the net-work are of very varying size and form.

Fig. 783.



Lymphatic capillary net-works within connective-tissue layer of skin; smaller vessels belong to superficial net-work, larger to deeper. (*Teichmann.**)

Fig. 784.



Transverse section of small lymph-vessel. × 210.

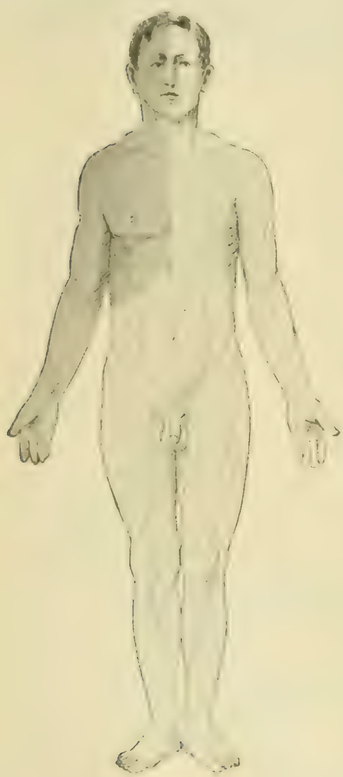
The arrangement assumed by a net-work depends largely upon the tissue and organ in which it occurs. In the integument, for instance, the lymph-capillaries arrange themselves in two more or less distinct layers, a more superficial one, composed of smaller capillaries, and a deeper, coarser one,—numerous communications necessarily existing between the two. Both net-works are confined to the dermis, the more superficial one lying close to its epidermal surface, while the deeper one is situated in its deeper layers, the distance between the two varying according to the development of the dermis in different portions of the body and in different individuals. From the superficial layer loops or single capillaries project upward into the dermal papillæ, and special portions of the net-work surround each hair-follicle and sudoriparous gland.

* Das Saugadersystem. Leipzig, 1861.

The mucous membranes have essentially the same arrangement, the net-work within the small intestine, for instance, being arranged in two more or less distinct layers, one of which lies in the submucosa and sends loops or blindly ending processes into the villi, while the other is situated in the muscular coat. What may be regarded as a third net-work, lying beneath the serous or connective-tissue investment, is formed by the anastomosis of the stems arising from the deeper net-works and it is from this last net-work that the efferent stems arise. In most other organs lined by mucous membrane a similar arrangement occurs, although in the uterus, bladder, and ureters the submucous net-work seems to be wanting, the muscular set alone being demonstrable. Throughout the serous membranes the net-works possess naturally a layered arrangement, but in the more massive organs, such as the liver and pancreas, they are arranged with reference to the constituent lobules, each being invested by an interlobular net-work.

Considerable variation exists in the closeness of the net-work in different organs, and, indeed, in different parts of the same organ, but everywhere the lymph-capillaries are exceedingly thin-walled and possess no valves. As has been pointed out, the view formerly prevailed that the capillaries communicated directly with the great serous cavities of the body, with the spaces of the connective tissues, and even with the pericellular spaces which occur in the more compact tissues, all these being regarded as radicles of the lymphatic vessels. It is now believed, however, that such is not the case, but that the net-works, which are everywhere continuous, are completely closed except for their communications with the efferent vessels.

FIG. 785.



Shaded part of figure shows area drained by right lymphatic duct; lymphatics of remaining territory received by thoracic duct.

The Lymph-Vessels.—The lymph-vessels, which issue from the capillary net-works and convey the lymph ultimately to the subclavian veins, have an arrangement closely resembling that of the veins, and, indeed, the larger ones are usually situated alongside and accompany the course of blood-vessels. Just as it is possible over the surface of the body and limbs to distinguish between superficial and deep veins, so there can be recognized a *superficial set* of lymphatic vessels (**vasa lymphatica superficialia**), situated superficially to the fascia which encloses the musculature, and a *deep set* (**vasa lymphatica profunda**), the vessels of which lie beneath the fascia ; numerous communications, however, exist between the two sets.

Just as the veins unite to form larger trunks as they pass from the capillaries toward their termination, so, too, the lymphatics ; but the latter present two peculiarities which distinguish them from the veins. They do not anastomose as abundantly as the latter and there is not the same proportional increase in the size of a lymphatic vessel formed by the junction of others as in the veins, so that, while the lymphatics at their origin from the capillary net-works may have the same calibre as the corresponding veins, yet their terminal trunks are of much smaller diameter.

As a rule, several lymphatic vessels arise from the capillary net-work of any organ or region of the body, and, since the net-work is to be regarded as practically continuous over large areas, it would appear that the flow of lymph from any circumscribed area might take place through widely separated stems and be carried along very different paths. And such, to a certain extent, is the case ; but it has been found by experiment and by the observation of pathological conditions that for each organ or region there is a more or less definite lymphatic path, each vessel or group of vessels tending to drain a somewhat definite area of the net-work, a fact of considerable importance from the diagnostic standpoint.

All the lymphatic vessels terminate directly or indirectly in one of two main trunks, which, as already stated, open respectively into the right and left subclavian veins. The left trunk, the **thoracic duct** (**ductus thoracicus**), is much larger than the right, beginning in the abdominal region and traversing the entire length of the thorax to reach its destination. It receives all the lymph returned from the lower limbs, the pelvic walls and viscera, the abdominal walls and viscera, the lower part of the right half and the whole of the left half of the thoracic wall, the left half of the thoracic viscera, the left side of the neck and head, and the left arm. The other trunk, the **right lymphatic duct** (**ductus lymphaticus dexter**), is very short, and, indeed, is frequently wanting, the vessels which typically unite to form it opening independently into the vein. It receives the lymph from the upper part of the right side of the thoracic wall, from the right half of the thoracic viscera and the upper surface of the liver, the right side of the neck and head, and from the right arm (Fig. 785).

In **structure** the larger lymphatic vessels are similar to the veins, but, as a rule, their walls are thinner than those of veins of corresponding calibre and their valves are more numerous. The walls of the most robust trunks, particularly those of the thoracic duct, consist of three coats. From within outward these are: (*a*) the *intima*, composed of the endothelial lining and the fibro-elastic subendothelial layer; (*b*) the *media*, made up of involuntary muscle interspersed with fibro-elastic tissue; and (*c*) the *adventitia*, consisting of fibro-elastic tissue and, frequently, of longitudinal bundles of involuntary muscle. (Fig. 784.)

The Lymphatic Nodes.—Scattered along the course of the lymphatic vessels are to be found in various regions of the body elliptical flattened nodules (Fig. 796) of varying size, sometimes singly but more frequently in chains or groups (**plexus lymphatici**) of from three to six or even ten to fifteen. These are the *lymphatic nodes* (**lymphoglandulae**). As it approaches a node, a lymph-vessel divides into a number of stems, the *vasa afferentia*, which enter the substance of the node and communicate with a capillary net-work in its interior, from which a somewhat smaller number of vessels, the *vasa efferentia*, arise (Fig. 786). These, leaving the node, the surface of which frequently presents a slight depression, the *hilum*, at their point of emergence, unite to form the continuation of the vessel.

FIG. 786.

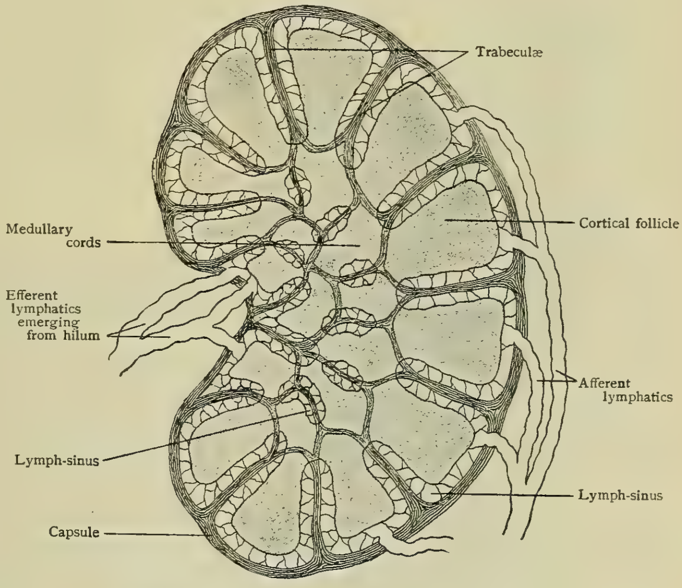


Diagram illustrating architecture of lymph-node.

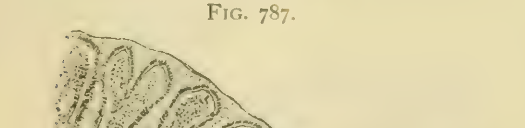
The lymph conveyed by any of the vessels traverses one or more nodes before emptying into the thoracic or right lymphatic duct, and in those cases in which a plexus occurs in a lymph-path a number of nodes must be traversed. The passage through the intranodular net-work produces a greater or less retardation of the flow of the fluid and affords opportunity for the accumulation of lymphocytes. Moreover, since these possess a phagocytic function, in cases of infection of any part of the body the nodes along the lymph-paths leading from it become more or less engorged with lymphocytes and enlarged, and in case the lymphocytes are unable to contend successfully with the infective material, the nodes may serve as

foci for its distribution to other parts of the system. The nodes therefore, serving as traps for the infective material, possess a high degree of importance from the surgical standpoint, an accurate knowledge of their location and of the lymph-paths along which each group is situated being of great value.

In addition to the ordinary lymph-nodes there occur in various regions of the body, especially in the prevertebral regions of the abdomen, structures which resemble lymph-nodes in their form and size, but differ from them in color. In general the lymph-nodes are of a pale pinkish color, although those in the vicinity of the lungs are usually blackish, from the deposition in them of dust particles from the lungs, and those in connection with the vessels arising from the small intestine are milky white during digestion. The structures in question, however, are of a deep red color, owing to the presence of abundant blood-vessels in their cortical portion. These bodies have been termed the **hemolymph nodes**, but their exact nature and function have not yet been definitely ascertained. By some they are regarded as special structures, quite different from the lymph-nodes, perhaps partaking somewhat of the character of the spleen; while others regard them as ordinary lymph-nodes with an especially rich blood supply, transitional forms between them and the usual lymph-nodes being believed to exist. Whether or not direct communication exists between the cortical blood-vessels and the medullary lymphatics within these hemolymph nodes is also a question concerning which differences of opinion exist.

Structure of Lymphoid Tissue.—Wherever found, whether as diffuse masses, simple nodules, or as the larger and more complex lymph-nodes, lymphoid or adenoid tissue is composed of two chief constituents, the supporting reticulum and the lymphoid cells contained within the meshes of the framework. The *reticulum* varies in the thickness of the component fibres and the size of its meshes, but in the denser types of lymphoid tissue, as seen in the periphery of the solitary nodules and in the cortical follicles and medullary cords of the lymph-nodes, it is so masked by the innumerable overlying cells that only after removal of the latter can the supporting framework be satisfactorily demonstrated. The reticulum, the nature of which is still a subject of discussion, may be regarded as modified fibrous connective tissue, upon the trabeculæ of which, particularly at the points of junction, flattened connective tissue cells are closely applied as a more or less complete investment. In certain localities where of exceptional delicacy, the reticulum may be formed almost entirely by the anastomosing processes of stellate connective-tissue elements.

FIG. 787.



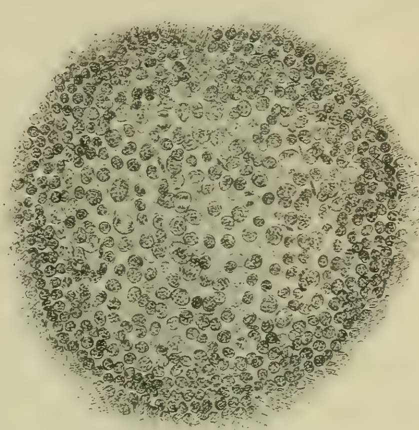
Simple lymph-nodule from large intestine. × 120.

The *cells* composing lymphoid tissue, exceedingly numerous and closely packed, present the general characteristics that distinguish the lymphocytes, being small elements with comparatively large nuclei, which exhibit a strong affinity for nuclear (basic) stains.

The **simple lymph-nodules**, of varying size but seldom more than 2 mm. in diameter, are irregularly spherical or elliptical masses of lymphoid tissue in which a denser peripheral zone encloses and blends with a core of less compact texture. Within the looser and therefore lighter central area, lymphoid cells in various stages of mitotic division are frequently seen, such foci, known as *germ-centres*, indicating

the birthplaces of new lymphocytes. Although the limits of the lymph-nodules are commonly imperfectly defined by a condensation of the surrounding connective tissue, a distinct capsule is usually wanting. Definite lymph-channels are found neither upon the surface nor within the simple nodules ; the latter are provided, however, with a generous net-work of capillary blood-vessels (Fig. 792).

FIG. 788.

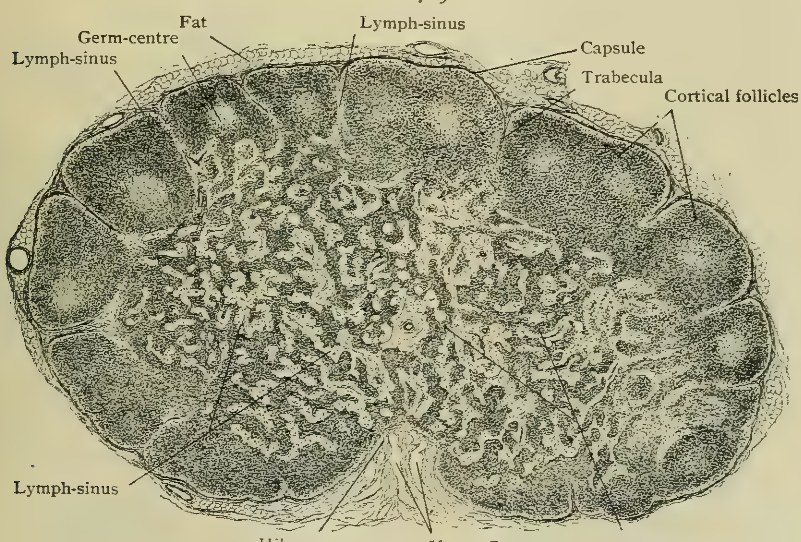


Portion of lymph-nodule, showing details of germ-centre. × 350.

Intermediate in their complexity of arrangement, between the simple nodules on the one hand and the typical lymph-nodes on the other, stand such structures as Peyer's patches and the faucial and pharyngeal tonsils, in which groups of simple nodules are blended into a single organ, the component follicles only partly retaining their individuality.

The **lymph-nodes** interposed along the lymphatic vessels, usually embedded within fatty tissue, represent still higher differentiation as distinct organs. In form and size they vary from minute bodies resembling millet-seeds to flattened oval or bean-shaped organs, that may measure almost an inch in their longest diameter. They are invested by a distinct fibrous *capsule*, in which elastic fibres constantly and unstriped muscle occasionally are present. From the deeper surface of this envelope numerous radially directed trabeculæ penetrate the outer zone, or *cortex*, which is thus subdivided into a series of pyramidal compartments. On reaching the inner limits of the cortical zone, the trabeculæ are less regularly disposed and more freely united, thereby breaking up the deeper parts, or *medulla*, of the node into uncertain cylindrical compartments. The spaces thus imperfectly defined by the trabeculæ are

FIG. 789.

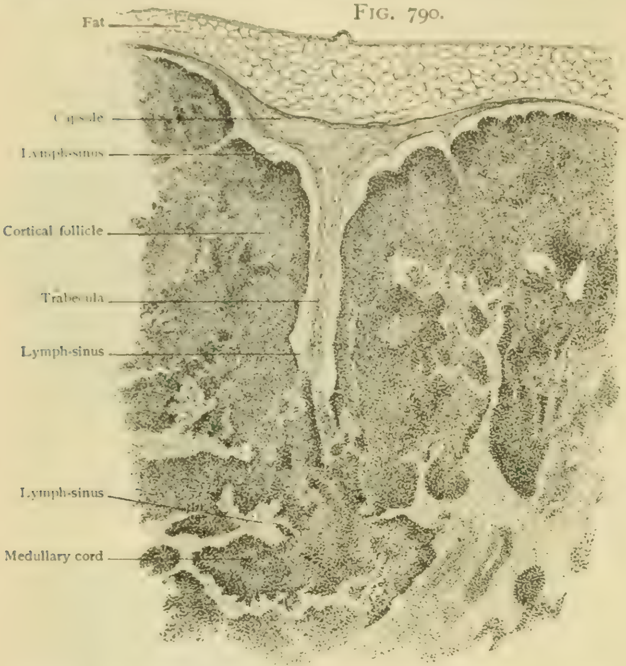


Section of small lymph-node through hilum. × 25.

incompletely filled by masses of compact lymphoid tissue, the general form and arrangement of which correspond to the compartments in which they lie. The masses contained within the peripheral spaces are spherical or pyriform and constitute

the *cortical nodules;* those within the communicating central compartments form a net-work of irregular cylinders, the *medullary cords*, which are continuous with one another and with the deeper part of the cortical nodules (Fig. 789).

FIG. 790.



Portion of periphery of lymph-node, showing relation between trabecula, sinus, and lymphoid tissue. × 50.

The intervals between the tracts of lymphoid tissue and the trabecular frame-work constitute a system of freely intercommunicating channels, the *lymph-sinuses*, through which passes the lymph brought to the node by the afferent lymphatic vessels. The latter pierce the capsule on the convex surface of the node and empty into the sinuses that surround the outer and lateral surfaces of the cortical nodules. After traversing the peripheral sinuses, the lymph passes into the irregular channels of the medulla and towards the point at which the efferent lymph-vessels leave the nodule. The position of this exit is usually indicated by a more or less pronounced indentation, known as the *hilum*, on the surface of the node opposite the entrance of the afferent lymph-vessels.

FIG. 791.

Portion of medulla of lymph-node, showing details of lymph-sinus and medullary cords. × 250.

The lymph-sinuses, therefore, are bounded on one side by the capsule or the trabeculæ and on the other by the masses of dense lymphoid tissue. The lumen of these channels, however, is not free, but occupied by a delicate wide-meshed reticulum consisting of fine strands of connective tissue where most marked, or of the processes of stellate cells where very delicate (Ebner). The sinuses are lined by an imperfect layer of flattened plate-like cells, that represent the endothelium of the adjoining lymphatic vessels and also cover the more robust trabeculæ crossing the channels. The reticulum occupying the sinuses is continuous with the closer and more delicate net-work within the adjacent dense lymphoid tissue. Although both the afferent and efferent lymphatics are provided with valves, the lymph-channels

within the node are destitute of such folds. The passage of the lymph through the nodes is retarded by the reticulum within the sinuses, thus favoring the entrance of the young lymphocytes from the surrounding lymphoid tissue into the sluggishly circulating fluid. Germ-centres, the particular foci for the production of the lymphocytes, usually are present within the cortical nodules, but are not found within medullary cords.

The **blood-vessels** for the nutrition of the lymph-nodes are numerous. Entering at the hilum, they divide into arterioles which follow the trabeculæ, giving off smaller branches that penetrate the medullary cords and the cortical nodules and break up into rich capillary net-works for the supply of the denser lymphoid tissue.

Fig. 792.

Cross-section of small lymph-node, injected to show rich vascular supply. × 10.

Both medullated and non-medullated **nerves** enter the node at the hilum in company with the blood-vessels. They are chiefly sympathetic fibres destined for the involuntary muscle of the vessels and of the capsule. The distribution of the medullated fibres is uncertain. According to Tonkoff, fibrillæ are traceable into the lymphatic tissue of the medulla.

Development.—The origin of the first *lymph-cells*, the lymphocytes, is uncertain, these elements appearing outside the vessels as derivatives from the mesoblast (page 688). After the establishment of the lymphoid tissue new cells are continually being formed within the various lymph-nodes and nodules.

The development of the **lymphatic vessels** has generally been believed to proceed from the veins by a process of budding (Ranvier), similar to that followed in the extension of the blood-vessels; and certain recent investigators,—Sabin,[1] who studied the development of the lymphatics in pig embryos, and F. T. Lewis,[2] who worked with rabbit embryos,—while differing as to details of the development of the definitive lymphatic stems, agree as regards their origin in this manner.

Sabin, by employing a method of injection, found that the first traces of a lymphatic system appear in pig embryos, 14.5 mm. in length, as two small outgrowths, which develop, one on each side, at the junction of the subclavian and jugular veins; from these, by a process of endothelial budding, vessels gradually grow towards the skin, radiating and anastomosing in all directions to form a subcutaneous net-work, which gradually extends throughout the anterior half of the body. Later two additional outgrowths develop at the junction of the femoral and post-cardinal veins, and give rise to a subcutaneous net-work throughout the posterior half of the body, the two sets of net-works thus formed eventually uniting.

Lewis's studies of serial sections of rabbit embryos gave somewhat different results and indicated that Sabin's method of study did not suffice to reveal the actual origin of the lymphatics. He found the first of these vessels along the course of the internal jugular vein as a series of spaces, each of which he supposed to represent an independent outgrowth from the vein. These spaces eventually fused to form a single lymph-channel accompanying each vein, and other channels were found to arise in a similar manner in connection with the subcardinal, mesenteric, and azygos

[1] Amer. Jour. of Anatomy, vol. i., 1902.
[2] Amer. Jour. of Anatomy, vol. v., 1905.

veins. The various channels finally unite to form a continuous system which acquires new openings with the venous system near the termination of the subclavian veins, the condition found in the adult being thus established.

More recently Huntington and McClure,[1] working with cat embryos, have also found the earliest traces of the lymphatic system in a series of spaces which appear in the tissue surrounding the intima of the anterior cardinal veins, but they found that these spaces have at first no connection with the veins, nor are they outgrowths from them. The anterior cardinal vein of each side is early divided longitudinally into two portions by the passage through it of the cervical nerves, and the dorso-lateral portion of the vein later undergoes retrogression, the ventro-medial portion persisting as the internal jugular. As the dorso-lateral portion shrinks, the lymphatic spaces along its course rapidly enlarge, fuse together, and form a large lymphatic stem, which subsequently makes connection with the subclavian vein, and thus forms the primary lymphatic trunk of the body (Fig. 793).

FIG. 793.

Developing lymphatics in rabbit embryo of 11 mm. (14 days); × 9. Lymphatic vessels are heavily shaded; veins are light. *In.J.*, *Ex.J.*, internal and external jugular veins; *Pr.U.*, primitive ulnar; *Ex.M.*, external mammary; *Az.*, azygos; *VCI.*, inferior vena cava; *G.*, gastric; *S.M.*, superior mesenteric; *V.*, vitelline; *Sc.*, subcardinal; *R.A.*, renal anastomosis of subcardinals; *Pr.Fi.*, primitive fibular; *c.b.*, connecting branch; *An.T.*, anterior tibial; *c.*, caudal; *3, 4, 5, 6*, position of corresponding cervical nerves. (*F. T. Lewis.**)

Later, spaces develop along the course of the anterior cardinal veins below the point where the subclavians open into them, but it is noticeable that those occurring in association with the left vein, which undergoes retrogression, develop more rapidly than those accompanying the same portion of the right vein and form the *thoracic duct* (Fig. 794), this structure thus belonging essentially to the left half of the body, since the principal persistent veins occur on the right side. Similar spaces appear in the peri-intimal tissue of other veins, and in all cases those associated with retrogressive veins are the most rapidly developed. While most of the principal lymphatic trunks unite with the thoracic duct, yet they may also form temporary or even permanent communications with other veins than the subclavian, certain of the adult anomalies being results of these connections.

From these observations it seems that the lymphatics arise from spaces which are primarily independent of, although associated with, the veins, and that, while this mode of origin of the lymphatics applies to those following the primitive systemic veins, yet the more peripheral portions of the system are developed by a process of budding from the main stems, just as is the case with the smaller branches of the blood-vessels. By this budding process the system gradually extends throughout the body, invading the various tissues, the invasion, however, failing to affect certain of the tissues, such as cartilage and the central nervous system.

The development of the **lymph-nodes** has been recently studied by Kling[2] and by Sabin.[3] According to the latter investigator, the lymph-nodes may be regarded as formed by two fundamental parts—the *lymphoid element*, consisting of lymphocytes in a reticulum surrounding the terminal artery and its capillaries within the

[1] Amer. Jour. of Anatomy, vol. vi., 1907. [2] Archiv f. mikros. Anat., Bd. 63, 1904.
[3] Amer. Jour. of Anatomy, vol. v., 1905. * Amer. Jour. of Anatomy, vol. v., 1905.

cords and germ-centres respectively, and the *sinus-element*, represented by channels resulting from the multiplication of the lymph-vessels. The former, or vascular factor, is constant and present in the simplest nodule; the sinus-element, on the contrary, varies, sometimes (as in the usual type of node) being developed from numbers of closely packed lymph-ducts and, therefore, of lymphatic origin, and at other times (as in the hemolymph nodes) being venous channels occupied by blood. By the subsequent intergrowth of the lymphoid element and the greatly multiplied lymph-capillaries, the intervening bridges of connective tissue are reduced in thickness until finally only the reticulum remains and the lymphoid tissue is ultimately brought into intimate relation with the surrounding sinus. In certain nodes the sinus retains its character as a direct outgrowth from the veins and becomes filled with erythrocytes. Such nodes assume the peculiarities of hemolymph nodes, in which the blood-sinuses replace those that convey lymph. As Sabin has emphasized, the follicle is the anatomical as well as the vascular unit, the simplest nodule consisting of a single follicle. The latter may be without a sinus, or surrounded by one which is either a lymphatic or a venous channel.

FIG. 794.

Developing lymphatics in rabbit embryo of 21 mm. (17 days); $\times$ 6. Lymphatic vessels are heavily shaded; veins are light; for significance of lettering see preceding figure; in addition, *Ce.*, cephalic; *Br.*, brachial; *R.*, radial; *Ss.*, subscapular; *Sci.*, sciatic; *Fe.*, femoral; *Il.*, iliolumbar. (*F. T. Lewis.**)

In describing the various lymphatic vessels and nodes it will be convenient to consider first the great terminal trunks of the system, the thoracic and right lymphatic ducts, and then discuss the remaining portions of the system from the topographical standpoint. Attention will be directed primarily to the nodes of each region, the course of the lymph-paths from each organ and their relations to the nodes being subsequently considered.

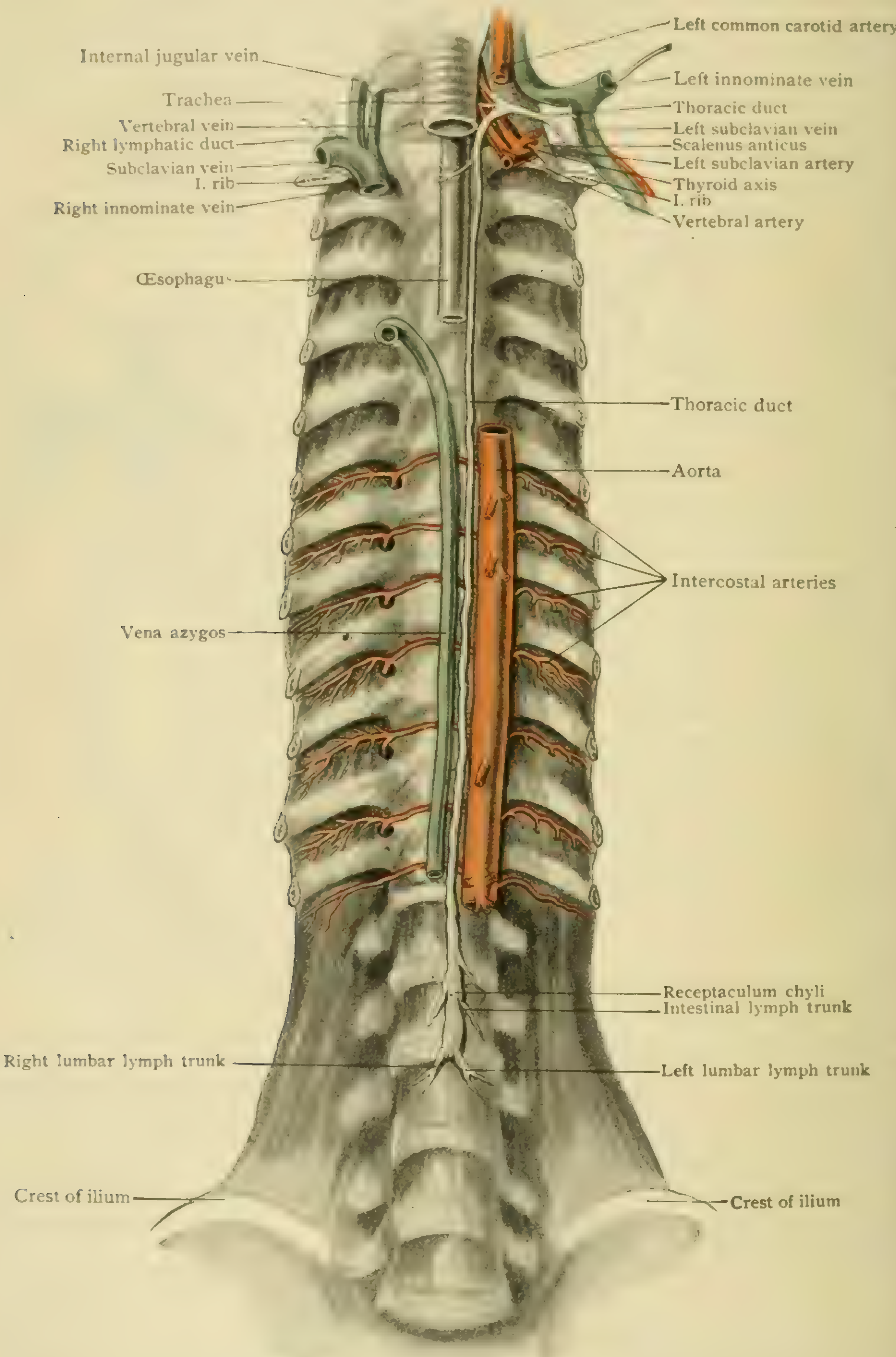
THE THORACIC DUCT.

The thoracic duct (**ductus thoracicus**) (Fig. 795) extends from the lower border of the second lumbar vertebra, through the entire length of the thorax, to open into the left subclavian vein close to the point where it is joined by the left internal jugular. Its entire length is from 43–46 cm. (17–18 in.). The duct lies at first in

* Amer. Jour. of Anatomy, vol. v., 1905.

front of the first and second lumbar vertebræ, and passes upward through the aortic opening of the diaphragm. In the thorax its course, although slightly sinuous, in

FIG. 795.



Dissection of posterior body-wall, seen from in front, showing thoracic duct and right lymphatic duct; veins have been laterally displaced to expose terminations of thoracic duct.

general is at first almost directly upward, a little to the right of the median line of the bodies of the thoracic vertebræ; at the level of from the sixth to the fourth

vertebræ, however, it begins to incline slightly towards the left, and, finally, at about the lower border of the seventh cervical vertebra it changes its direction somewhat abruptly, passing upward, forward and to the left, and then downward and forward, thus forming an arch whose convexity is directed upward and whose extremity opens into the subclavian vein.

The thoracic duct is formed by the union of the right and left lumbar trunks (**trunci lumbales**) which drain the lumbar nodes. The left trunk, shortly before its union with the right, is usually joined by an unpaired intestinal trunk (**truncus intestinalis**) that drains the cœliac and mesenteric nodes. Just above its commencement the thoracic duct usually, although not always, presents a pyriform enlargement, the **receptaculum chyli** (cisterna chyli), which extends upward as far as the level of the eleventh thoracic vertebra, and measures from 5–7.5 cm. (2–3 in.) in length and from 6–8 mm. in diameter. Above the eleventh thoracic vertebra the duct gradually diminishes in calibre until about the middle of its course, where it again enlarges. The thoracic duct possesses few valves in comparison with other lymphatic vessels, those which do occur being frequently insufficient. Its entrance into the subclavian vein, however, is guarded by two well-developed leaflets, which prevent the passage of blood into the duct.

Relations.—In its *abdominal portion* the thoracic duct lies almost in the median line in front of the bodies of the first two lumbar and twelfth thoracic vertebræ, and between the crura of the diaphragm, or under cover of the right crus. Anteriorly, it is in relation with the right side of the abdominal aorta, with the greater azygos vein to the right.

In its *thoracic portion* it lies at first within the posterior mediastinum, but above, it enters the superior mediastinum. In the former it lies anterior to the bodies of the eleventh to the fifth thoracic vertebræ, and has in front of it, from below upward, the pericardium, the œsophagus, and the arch of the aorta. The thoracic aorta lies to the left of it, and to the right are the right pleura and the greater azygos vein. The lower right intercostal arteries pass between it and the bodies of the vertebræ, as does also the terminal portion of the hemiazygos vein. In the superior mediastinum it rests upon the lower part of the left longus colli muscle, being separated by it from the bodies of the upper three thoracic vertebræ. Anteriorly, it is in relation with the origin of the left subclavian artery and with the vertebral vein ; to the left is the left pleura and to the right are the œsophagus and the left recurrent laryngeal nerve.

Its *arch* is in relation below with the apex of the left lung and with the left subclavian artery ; to the left and posterior to it is the vertebral vein and to the right and anteriorly are the left common carotid artery, the left internal jugular vein, and the left pneumogastric nerve.

Tributaries.—In addition to the right and left lumbar and the intestinal trunks by whose union it is formed, the thoracic duct receives on either side (1) near its origin, a *descending trunk* which drains the posterior nodes of the lower six or seven intercostal spaces ; (2) an *ascending stem* from the upper lumbar nodes which traverses the crus of the diaphragm and joins the duct at about the level of the ninth or tenth thoracic vertebræ ; (3) the *efferent vessels* from the upper posterior intercostal nodes, which sometimes unite to form a single ascending stem opening into the upper part of the duct ; (4) the *efferent vessels* of the posterior mediastinal nodes ; (5) the *left jugular trunk ;* and, occasionally, (6) the *left subclavian* and (7) the *left bronchomediastinal trunks*, these last three uniting with the duct just before it opens into the subclavian vein.

Variations.—The thoracic duct is subject to numerous variations, so much so that certain authors have regarded as typical arrangements which others have considered to be abnormal.

Its origin is frequently opposite the body of the first lumbar vertebra or even opposite the last thoracic ; and rarely it is below the lower border of the second lumbar. Instead of being formed by the union of only two trunks, three are frequently found participating in its origin, the odd one being the intestinal trunk which usually opens into the left lumbar trunk. Occasionally all three trunks are represented by a number of smaller stems which anastomose with one another as well as with the descending stems from the posterior intercostal nodes, the plexus so formed communicating by a number of efferents

with the receptaculum chyli. It must be remembered that embryologically what are usually termed the origins of the thoracic duct are in reality its prolongations, that is to say, outgrowths from it, so that possibilities for variation in these stems are abundant.

In another respect the embryological history of the duct probably throws light upon its anomalies. In the rabbit the spaces formed along the course of the left posterior cardinal vein frequently unite to form two more or less distinct, parallel stems, which together represent the thoracic duct (Fig. 794). Whether this condition also exists in man is unknown, but if it does then an explanation is afforded for one of the most frequent anomalies of the duct, namely, its division in its lower part into two parallel stems which unite again after a longer or shorter independent course. This condition is so frequent that it has been regarded as typical by some authors ; usually the union of the two stems occurs at about the level of the seventh thoracic vertebra, but occasionally they remain separate throughout the entire length of the thorax and may be connected by transverse anastomoses.

Another group of anomalies, probably having a quite different embryological basis, includes cases in which there are either two distinct thoracic ducts, or else a single one which branches in its upper part, one of the two stems in either case passing to the left subclavian vein and the other to the right. This condition is due to the fact that the lymphatic system is symmetrical in its embryological origin, a trunk arising in connection with the right azygos vein as well as with the left. Ordinarily the left trunk, developing more rapidly than the right, becomes the thoracic duct, while the right outgrowth remains short and forms the right lymphatic duct. Conditions might occur, however, in which the right trunk would undergo a more extensive development and either unite with the left trunk or grow downward to form a second thoracic duct, thus producing the conditions under discussion. A further modification along the same line would lead to the development of the thoracic duct from the right trunk, the left giving rise only to a short lymphatic duct, an exact reversal of the normal arrangement being thus produced. Several such cases have been recorded, and it is interesting to note that they frequently accompany abnormalities of the aortic arch, such as the origin of the right subclavian from the descending portion; the anomaly also occurs, however, independently of any variation in the blood-vessels.

Considerable variation exists in the level to which the arch of the thoracic duct rises in the neck, and it is stated that it may lie anywhere between the levels of the fifth cervical and first thoracic vertebræ.

Likewise, variations in the mode of termination of the thoracic duct are often observed. It may open into the subclavian vein at some distance from the junction of the internal jugular, or, occasionally, into its posterior surface, and not infrequently it divides near its termination into two or more stems (Fig. 795), which may open into the internal or the external jugular or into the azygos or vertebral veins as well as into the subclavian. The connection with the azygos vein is probably of frequent occurrence.

Practical Considerations.—The thoracic duct may be *obstructed* by (*a*) aneurism of the arch of the aorta ; (*b*) enlarged mediastinal nodes (tuberculous, lymphadenomatous, or carcinomatous) ; (*c*) mediastinal neoplasms—especially if in the anterior mediastinum ; (*d*) exophthalmic goitre (very rarely) ; (*e*) thrombosis of the left innominate vein or of the subclavian at its junction with the internal jugular ; (*f*) tricuspid incompetence (through backward pressure) ; (*g*) cardiac hypertrophy ; (*h*) dense pancreatic growths (Agnew) ; (*i*) thrombosis (tuberculous) of the duct itself ; (*j*) filarial disease (obstruction by the parent worms) ; (*k*) cicatricial contraction or adhesion involving the duct ; (*l*) disease (tuberculous, carcinomatous) of the walls of the duct.

The duct may be *injured* (*a*) during operations—as for growths or enlarged glands—or by stab or bullet wounds (usually in its cervical portion) ; or (*b*) by grave trauma, as fracture dislocation of the spine (usually in the thoracic or abdominal portion), or violent compression of the thorax ; or (*c*) by muscular effort or during a paroxysm of vomiting (Busey), or whooping-cough (Wilhelm).

The fact that the duct as a rule extends upward but little if at all above the level of the junction of the internal jugular and subclavian renders operative injury of it rare, but as it occasionally is found higher, and may even extend to 5.5 cm. (2¼ in.) above the upper border of the sternum, its possible presence and its relations and variations (*vide supra*) should not be forgotten during extensive operations at the base of the neck on the left side.

The *results* of obstruction of the thoracic duct are (*a*) increased pressure and dilatation of the vessels behind the obstruction ; (*b*) the establishment of collateral circulation and entrance of lymph into the general circulation; or—if such collateral circulation is not established—(*c*) leakage by transudation into the surrounding tissues, into the pleural cavity (rare), or into the peritoneal cavity ; or (*d*) rupture of the duct or its tributaries. The stomata of the thin-walled

lymphatic vessels offer little obstacle to free transudation, which, when it follows obstruction, may be compared to the hematemesis seen in hepatic cirrhosis (Rolleston).

The symptoms of obstruction are neither so constant nor so marked as they would be if it were not that (*a*) the lymphatic system is not, like the veins, a series of closed vessels, but is practically continuous with the interstices of the tissues; and that (*b*) it communicates with the venous system, the duct itself with the azygos vein in the posterior mediastinum, and the smaller lymphatics with venules elsewhere—certainly, for example, in the inguinal region, and probably in other parts of the body (Leaf).

The effects of obstruction are most often noticeable when the interference with the flow of lymph takes place near the termination of the duct on the outer side of the internal jugular vein, near its junction with the subclavian. This is probably due to (*a*) the frequency of tumor or of injury in this situation; (*b*) the consolidation of the lymph-vessels here into a single trunk; (*c*) the greater difficulty in establishing a compensatory collateral circulation between the parts of the duct above and below the obstruction than if the latter were lower down (Rolleston).

Chylous ascites may be due either to obstruction with transudation of chyle from distended lacteals into the peritoneal cavity, or to wound or rupture of the thoracic duct, or of the larger lymph-vessels, or of varicose lymph-vessels, or of lymphangiomata. *Chylous pleural effusions* may similarly result, or an effusion following wound or rupture may be partly thoracic and partly abdominal, as in a case in which, after extreme compression of the chest, death followed in three weeks, and the thoracic duct was found ruptured where it traversed the hiatus aorticus (Bellamy).

When the receptaculum chyli is involved, the thoracic duct above may be quite healthy, and lymph may pass into it by anastomotic channels and no chylous ascites be produced.

Carcinoma of the aortic or mesenteric nodes may cause enough dilatation of the lymphatics to bring about chylous ascites.

THE RIGHT LYMPHATIC DUCT.

The right lymphatic duct (**ductus lymphaticus dexter**) (Fig. 795) opens into the right subclavian vein and is a very short stem, rarely having a length of more than from 10–12 mm. It is formed by the union of the right jugular and subclavian lymphatic trunks, the right broncho-mediastinal trunk rarely contributing to its formation, but having usually an independent opening into the subclavian vein. Very frequently no right lymphatic duct exists, the jugular and subclavian trunks, as well as the broncho-mediastinal, opening independently into the vein.

THE LYMPHATICS OF THE HEAD.

The Lymph-Nodes.

The lymphatic nodes of the head are arranged in groups, which, for the most part, are situated along the line of junction of the head and neck regions, that is to say, along a line extending from the external occipital protuberance to the temporo-mandibular articulation and thence along the rami of the mandible. A few small nodes also occur upon the cheeks, and others which lie upon the surfaces of the hyo-glossus and genio-hyo-glossus muscles and upon the upper part of the posterior surface of the pharynx may be regarded as belonging to the head region. Including these, the various groups recognizable in the region are (1) the *occipital*, (2) the *posterior auricular*, (3) the *anterior auricular*, (4) the *parotid*, (5) the *submaxillary*, (6) the *submental*, (7) the *facial*, (8) the *lingual*, and (9) the *retropharyngeal* groups.

The **occipital nodes** (**lymphoglandulae occipitales**) are from one to three in number and are situated at the base of the occipital triangle, immediately lateral to the border of the trapezius muscle and resting upon the upper part of the semispinalis capitis (Fig. 796). Their *afferents* come from the occipital portion of the scalp and their *efferents* pass to the upper nodes of the superior deep cervical group.

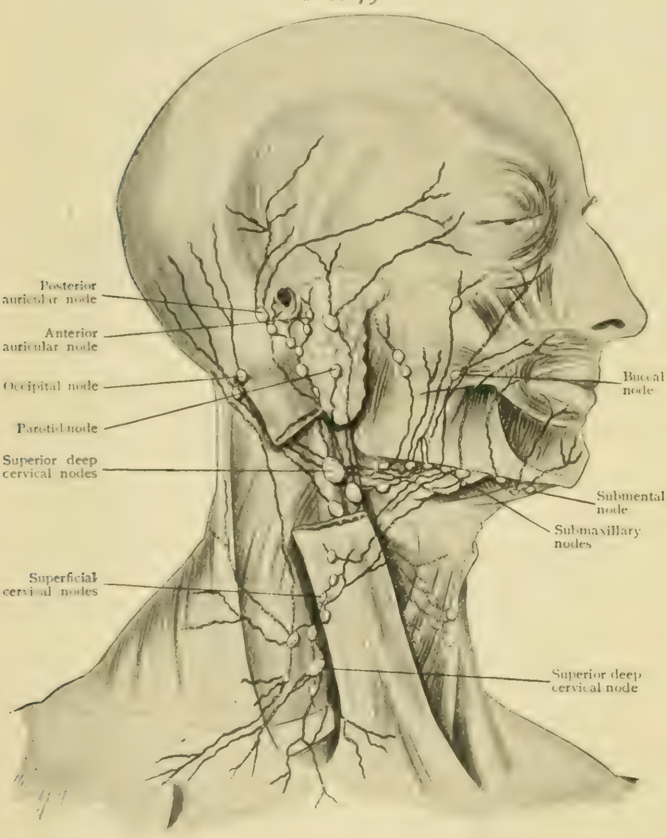
The **posterior auricular** or **mastoid nodes** (**lymphoglandulae auriculares posteriores**) are usually two in number and are of small size; they rest upon the mastoid portion of the insertion of the sterno-cleido-mastoid muscle (Fig. 796).

Their *afferents* are from the temporal region of the scalp, from the posterior surface of the pinna and of the external auditory meatus. Their *efferents* pass to the upper nodes of the superior deep cervical group.

The **anterior auricular nodes** (**lymphoglandulae auriculares anteriores**) vary from one to three in number and are situated immediately in front of the tragus, beneath the parotid fascia. Their *afferents* come from the anterior surface of the pinna and of the external auditory meatus, from the integument of the temporal region, and from the outer portions of the eyelids. Their *efferents* pass to the superior deep cervical nodes.

The **parotid nodes** (**lymphoglandulae parotideae**) are situated in the substance of the parotid gland (Figs. 796, 801). They are quite numerous and vary greatly in size. They receive *afferents* from the same regions as the anterior auricular nodes, and the lower nodes of the group also receive stems from the soft palate. Their *efferents* pass to the superior deep cervical nodes.

FIG. 796.



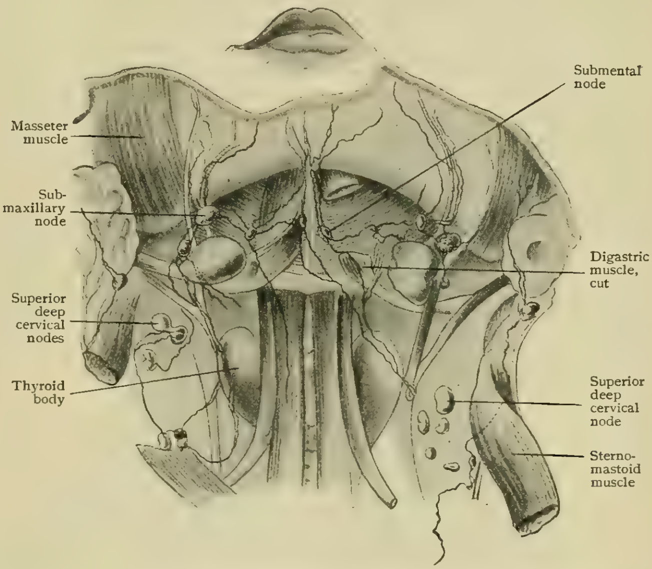
Superficial lymphatic vessels and nodes of head and neck; semidiagrammatic.

The **submaxillary nodes** (**lymphoglandulae submaxillares**) are from three to eight or more in number, forming a chain along the lower border of the horizontal ramus of the mandible, as far forward as the attachment of the anterior belly of the digastric muscle (Fig. 796). One node which rests upon the facial artery just before it passes over the ramus of the mandible is larger than the rest, and this, together with two others, which are somewhat smaller and lie one on either side of the larger node, are the most constant representatives of the group, the remaining nodes being usually still smaller and varying both in number and position. Occasionally a small node occurs imbedded in the substance of the submaxillary gland. These nodes receive, as *afferents*, vessels from the submental and facial nodes and also directly from the territory drained by the latter, namely, the upper lip, the outer surface of the nose and the cheek, from the inner portions of the eyelids, from the lower lip, the gums of both jaws, and from the anterior part of the tongue. Their *efferents* descend upon the surface of the submaxillary gland to open into the superior deep cervical nodes, especially into those situated in the neighborhood of the bifurcation of the common carotid artery.

The **submental nodes** are two or sometimes three in number, and are situated in the triangular space included between the anterior bellies of the two digastric muscles, each of the two principal nodes resting upon the inner border of one of the

muscles (Figs. 796, 797). They receive *afferents* from the integument of the chin, from the lower lip, and from the floor of the mouth; their *efferents* pass partly to the submaxillary nodes and partly to a node of the superior deep cervical group situated on the internal jugular vein a little above the level at which it is crossed by the omo-hyoid muscle.

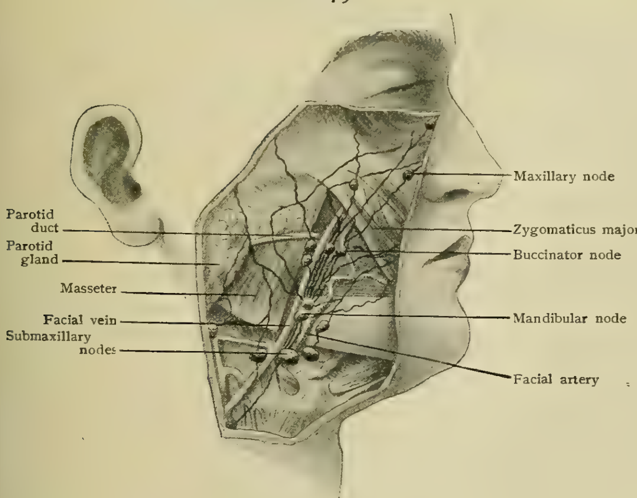
FIG. 797.



Submaxillary and submental lymph-nodes, new-born child. (*Stahr.**)

The **facial nodes** (**lymphoglandulae faciales profundae**) consist of several small groups (Fig. 798). One of these is composed of two or three nodes situated upon the outer surface of the horizontal ramus of the mandible, in front of the anterior border of the masseter muscle; these may be termed the **mandibular nodes.** A second group is to be found resting upon the surface of the buccinator muscle, and its nodes are therefore termed the **buccinator nodes.** They are three or four in number and are situated in the interval between the facial vein and artery, or posterior to the vein, almost opposite the angle of the mouth and either beneath or slightly below the zygomaticus major. A third group is formed by the **maxillary nodes,** which are somewhat scattered, one or two occurring in the groove formed by the junction of the nose and cheek, while another rests upon the malar bone near the lower border of the orbit. These maxillary nodes are normally quite small and may readily be overlooked.

FIG. 798.



Facial lymph-nodes. (*Trendel.*†)

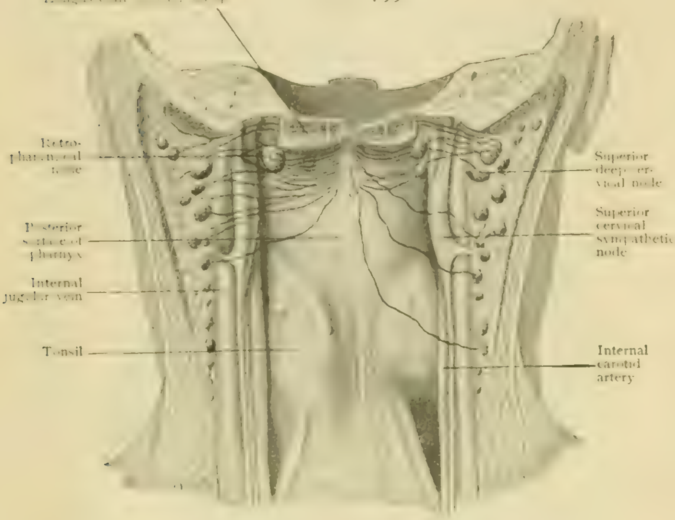
The *afferents* for the various groups of facial nodes take their origin in the upper lip, in the integument and mucous membrane of the nose and cheek, and probably also in the eyelids, the conjunctiva, and the lachrymal gland. Their *efferents* pass to the submaxillary nodes.

The **lingual nodes** (**lymphoglandulae linguales**) are a number of small enlargements situated upon the vessels which drain the lymphatic capillaries of the tongue. They do not possess any very definite grouping and are to be found upon both

* Archiv f. Anat. u. Physiol., 1898.
† Beiträge zur klin. Chirurgie, Bd. 39.

surfaces of the hyo-glossus muscle and in the interval between the two genio-hyo-glossi. From the surgical standpoint they are of comparatively little importance, and have been termed "intercalated nodes," to distinguish them from the true terminal nodes of the lingual lymphatics (page 954), in which enlargement occurs in cases of cancerous or other infection of the tongue.

Fig. 799.



Retropharyngeal lymph-nodes. (*Most.**)

The **retro-pharyngeal nodes** are for the most part small, appearing as slight enlargements of the lymphatics which drain the posterior surface of the pharynx. In addition to these "intercalated nodes," however, one or two much larger nodes occur at the junction of the lateral and posterior surfaces of the pharynx, about on a level with the anterior arch of the atlas. They are imbedded in the bucco-pharyngeal fascia and rest upon the lateral portions of the rectus capitis anticus major. *Afferents* come to them from the upper part of the pharynx and from the mucous membrane of the nose, and their *efferents* pass to the upper deep cervical nodes (Fig. 799).

The Lymphatic Vessels.

The Scalp.—The lymphatics of the scalp form a rich net-work, which is especially dense in the neighborhood of the vertex, the meshes becoming more elongated as the vessels pass away from the median line. From the frontal region some ten to twelve vessels pass downward and backward to terminate in the parotid nodes; from the parietal and temporal regions from six to ten vessels pass downward, some in front of the external auditory meatus to terminate in the anterior auricular and parotid nodes, and some behind the meatus to reach the posterior auricular nodes; and from the occipital region the more posterior vessels pass downward, partly to the occipital and partly to the superior deep cervical nodes, while the more anterior five or six converge to form a single large trunk which descends along the posterior border of the sterno-cleido-mastoid muscle and terminates in the inferior deep cervical nodes.

The Brain and the Meninges.—No lymphatic vessels have as yet been certainly demonstrated either in the central nervous system or in the meninges, although they have been described as accompanying the middle meningeal artery in the dura mater and the middle cerebral artery in the pia (Poirier). **Lymph-spaces,** however, some of them of considerable size, are abundantly present. Of these there may be mentioned, first, the *pericellular spaces* which surround the individual cells of the brain and spinal cord, both the actual nerve-cells and the neuroglia-cells, those accompanying the latter extending along their processes to communicate with an epicerebral space believed to exist between the surface of the brain and the pia (His), and also with spaces which occur along the course of the cerebral blood-vessels. Of this second group of spaces, the *perivascular spaces*, two sets have been described, one occurring in the adventitia surrounding the vessels and the other between the adventitia and the brain substance, and, accompanying the blood-vessels into the pia,

* Archiv f. klin. Chirurgie, Bd. 41, 1900.

they communicate with the subarachnoid spaces. The third group of spaces is formed by the *subdural* and *subarachnoid spaces*, but no special description need here be given of these, since they are more properly described (page 1197) as portions of the meninges than as parts of the lymphatic system. By some authors an *epidural* space, situated between the dura and the skull, is also recognized.

Lymph-spaces have been described as occurring in the substance of both the dura and the pia, forming in the latter a rather close net-work with which the perivascular spaces communicate. The spaces of both membranes communicate with the subdural space, and those of the dura are said also to communicate with the epidural space.

Practically nothing is yet known concerning the lymphatics of the spinal cord.

The Eye and Orbit.—No lymphatic vessels have as yet been described as occurring in the orbital tissues, nor do they occur in the eyeball. But, on the other hand, numerous lymph-spaces occur in connection with the latter structure, one of the most important of these being the **space of Tenon** (**spatium interfasciale**), with which the remaining spaces communicate more or less directly (Fig. 800). A description of this space has already been given (page 504), but it may be recalled that, in the first place, the space is continued, by means of the supravaginal lymph-

FIG. 800.

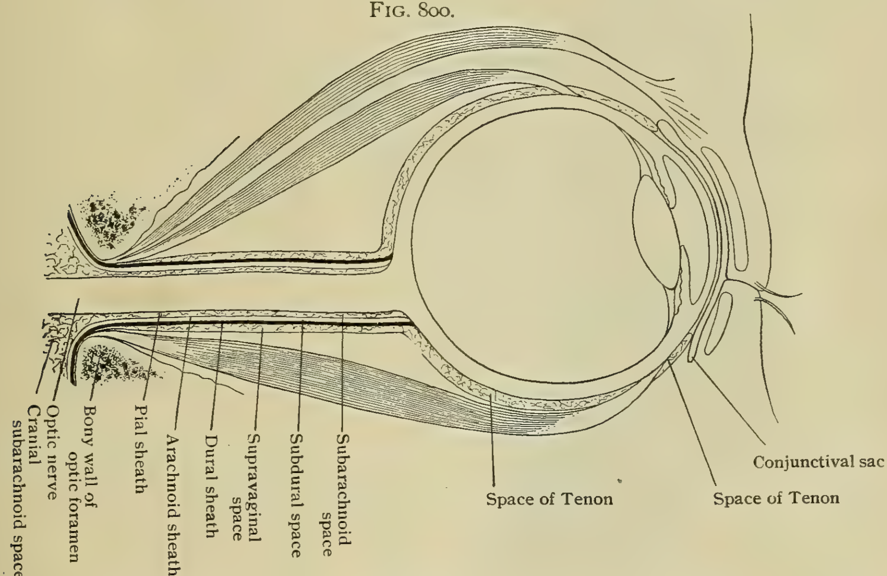


Diagram showing relation of space of Tenon to intracranial lymph-spaces.

path surrounding the optic nerve, along the latter to the apex of the orbit, where it communicates with the subdural space of the cranium, injection of that space resulting in the injection of the space of Tenon (Schwalbe), and, secondly, that the sheaths of the anterior portions of the orbital muscles are formed by reflections of the capsule of Tenon, so that no obstacles exist in the way of the passage of lymph from the muscles into the space.

The cavities occupied by the vitreous and aqueous humors have also been regarded as lymph-spaces, and pericellular spaces in the cornea, which come into relation with the lymphatic vessels of the conjunctiva at the corneal margin, are readily demonstrable. In the tissue of the sclerotic spaces also occur, communicating on the one hand with the space of Tenon and on the other with suprachoroid spaces which are abundantly present in the lamina fusca of the choroid coat and, by means of spaces accompanying the venæ vorticosæ, communicate with the space of Tenon.

In the eyelids, conjunctiva, and lachrymal apparatus true lymphatic vessels occur. In the eyelids three net-works have been distinguished, one of which is subcutaneous, the second lies immediately external to the tarsal plate, and the third is subconjunctival. Communicating branches pass between adjacent plexuses, especially between the

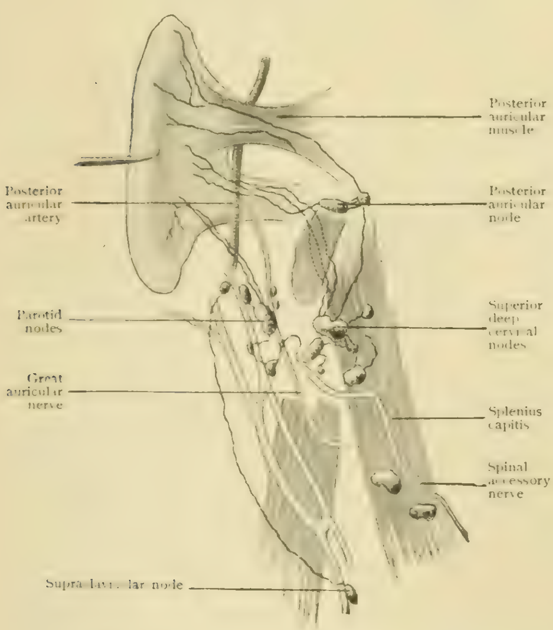
subcutaneous and prætarsal ones, and all three are united at the palpebral margins in a rather finely meshed plexus. Efferents pass both toward the inner and the outer angle of the orbit, and the former pass downward, obliquely across the cheek, in company with the facial vein, to terminate in the submaxillary nodes, possibly making connections with some of the facial nodes on their way (Fig. 798). The outer ones pass partly to the anterior auricular and partly to the upper parotid nodes.

In the conjunctiva two net-works occur, one situated in the superficial and the other in the deeper layers of the conjunctival dermis. Communicating stems pass between the net-works, which are much finer in the neighborhood of the corneal margin than more peripherally. They come into relation with the pericellular lymph-spaces of the cornea, and their efferents pass toward the outer and inner angles of the orbit, to accompany the palpebral efferents to the submaxillary, posterior auricular, and parotid nodes.

Of the lymphatic vessels of the lachrymal gland but little is known, but in malignant diseases of the gland enlargement of some of the facial and anterior auricular nodes has been observed, and it is probable that vessels from the gland accompany the palpebral and conjunctival efferents. The vessels from the nasal duct probably partly accompany branches of the facial vein to the facial nodes, while those from its lower portion pass with the efferents from the nasal mucous membrane to the retropharyngeal and superior deep cervical nodes.

The Ear.—No true lymphatics have yet been observed in the tissues of the *internal ear*, but the space which intervenes between the osseous wall of the ear cavity and the membranous ear has been regarded as a lymph-space, and on that account has been termed the *perilymphatic space.* It communicates with the subdural space of the cranium by the aqueductus cochleæ and by the prolongations of it which accompany the ductus endolymphaticus and the auditory nerve.

Fig. 801.



Lymphatics of posterior surface of auricle of new-born child. (*Stahr.**)

In the *middle ear* spaces have been observed in the connective tissue lining the bony walls, as well as in that of the tympanic membrane. In addition a feebly developed net-work has been described as occurring beneath the epithelium lining the inner (tympanic) surface of the tympanic membrane, efferents from it accompanying the tympanic artery and terminating in the parotid nodes.

Much more extensively developed are the lymphatic vessels of the *external ear.* Beneath the epithelium covering the outer (meatal) surface of the tympanic membrane there is a very fine net-work, whose efferents accompany the blood-vessels, radiating toward the periphery of the membrane, and eventually open partly into the posterior and partly into the anterior auricular nodes. A net-work also occurs throughout the entire extent of the external auditory meatus, its efferents having the same destination as those of the pinna.

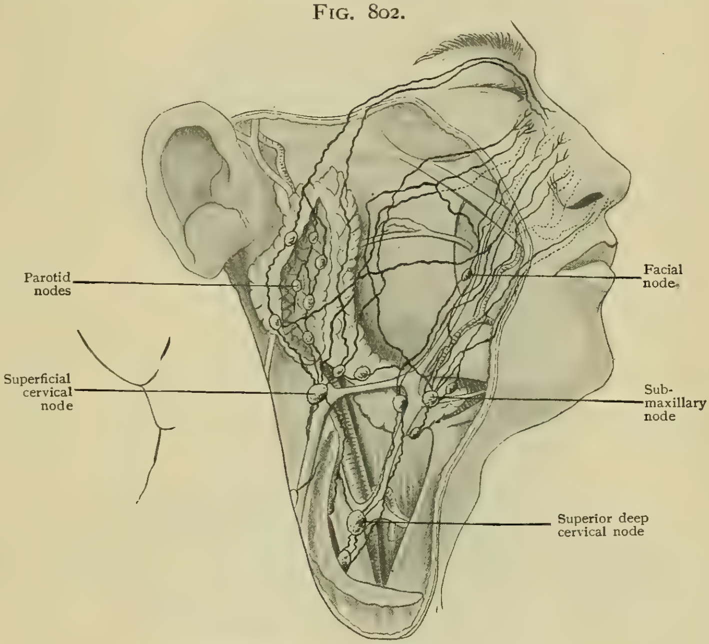
The vessels of the last named portion of the ear form a rich net-work extending throughout the whole extent of the organ, and from it stems pass in three principal

* Anatom. Anzeiger, Bd. xv., 1899.

directions; it must be recognized, however, that this classification of the stems into three groups does not imply a corresponding division of the net-work into distinct areas, since there is a considerable overlapping of the areas drained by the various stems, and, indeed, stems from the same region may pass in some cases with one of the group, and in others with another. From the outer (anterior) surface the stems pass mainly to the anterior auricular nodes, a few bending backward over the helix and terminating in the posterior auricular nodes. From the upper part of the posterior surface (Fig. 801) the stems pass mainly to the posterior auricular nodes, some, however, continuing past them to terminate in the external jugular nodes. From the lower part of the pinna, including the lobule, a number of stems pass to the parotid nodes.

The Nasal Region.—The lymphatic vessels of the integument of the nose (Fig. 802) form numerous anastomoses with those of the mucous membrane, especially with those of the middle and inferior meatuses, and those of the one side of the nose are also continuous with those of the other side. Some of the vessels which drain the upper portion of the nasal integument pass almost directly backward to the parotid nodes, but the principal path, followed by vessels from all parts of the nasal integument, is downwards and backwards across the cheek, in company with the facial blood-vessels. In their course some of them traverse some of the facial nodes, which appear as if intercalated in their course, but the majority pass directly to the submaxillary nodes.

FIG. 802.



Lymphatics of nose and cheek. (*Küttner*.*)

A rich lymphatic net-work lies beneath the mucous membrane of the nasal cavities, and from it vessels pass in two directions. Those of the anterior and lower portions of the fossæ pass forward and, partly at the external nares and partly by passing between the nasal bones and the cartilages, communicate with the superficial nasal lymphatics. The majority of the vessels, however, take a backward course, terminating in different node groups. Some join the vessels draining the palate and tonsils to pass to the superior deep cervical nodes and especially to that one which is situated in the angle formed by the union of the facial and internal jugular veins, while the rest unite to form from two to four stems which pass over the lateral surface of the pharynx and terminate in the retropharyngeal nodes.

The lymphatics of the sinuses which open into the nasal cavities follow, in part at least, the same courses as those of the nasal mucous membrane, their principal termination being in the larger retropharyngeal nodes.

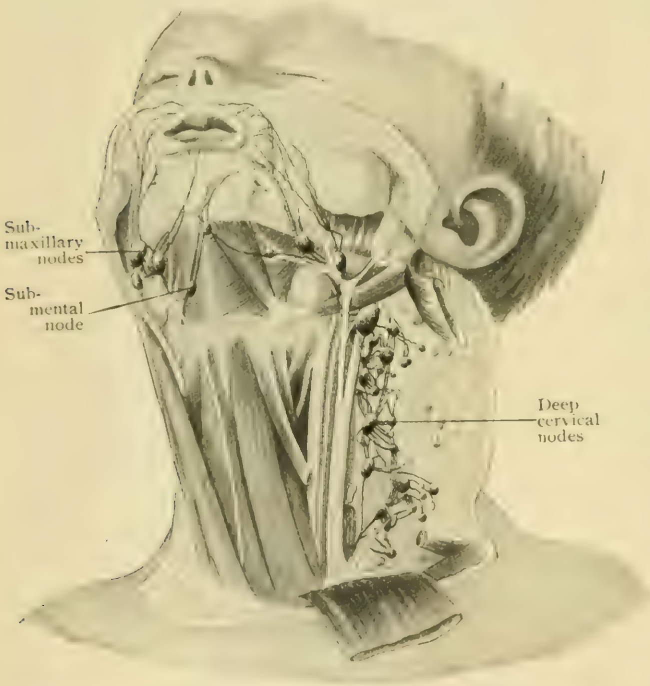
The Cheeks, Lips, Gums, and Teeth.—The lymphatics from the more posterior portions of the cheeks empty into the parotid nodes; those from the more anterior portions pass to the submaxillary nodes, and the deeper ones communicate with the facial nodes.

* Beiträge f. klin. Chirurgie, Bd. xxv., 1899.

The vessels from the submucous tissues of the lips pass mainly to the submaxillary nodes, two or three stems passing from the lower lip and one or two from the upper. Those of the *lower lip* pass downward and outward toward the facial artery and follow its course into the submaxillary region, while those from the upper lip are directed at first almost horizontally outward toward the facial vein, whose course they follow toward their termination. No anastomoses occur between the submucous vessels of the two sides in either lip.

The subcutaneous vessels of the *upper lip* (Fig. 803) have a course similar to that of the corresponding submucous stems, with which they may unite, and they terminate principally in the submaxillary nodes, although communication may also be made with one of the lower parotid nodes. The subcutaneous vessels of the lower lip are from two to four in number, and pass principally to the submental nodes, from which efferents pass to the submaxillary and superior deep cervical nodes. A noteworthy peculiarity of these lower lip vessels, which is in marked contrast with what obtains in the submucous stems, is that those of the right and left halves of the lip anastomose, so that an injection may pass from the vessels of the right half into the left submental and submaxillary nodes.

Fig. 803.



Subcutaneous lymphatics of lips and superior deep cervical nodes, new-born child. (*Dorendorf.**)

The lymphatics of the *lower gums* form a very rich net-work from which from fourteen to seventeen stems arise. These empty into a single large collecting stem on either side, which passes outward over the outer surface of the mandible and, opposite the last molar tooth, dips downward to terminate in the submaxillary nodes. Whether or not the pulp of the teeth contains lymphatic capillaries is a disputed question. All attempts to inject them have failed, but it has been maintained that their existence has been demonstrated by histological methods. Enlargement of the submaxillary nodes has been observed to follow dental lesions, but this may be due to the involvement of the tissues of the gums rather than to that of the tooth pulp.

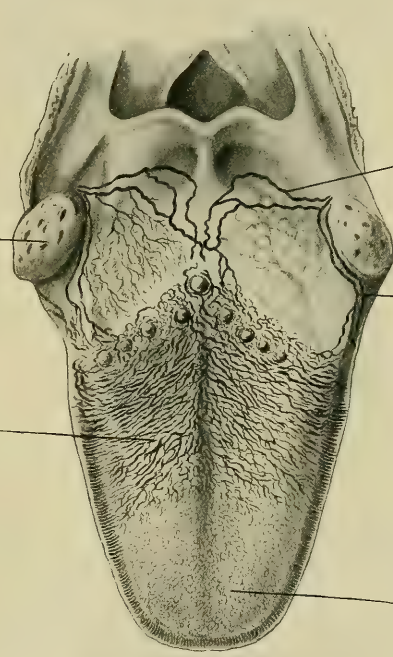
The Tongue.—The lymphatics of the tongue (Fig. 804) are divisible into two groups according as they arise in the submucous tissue or in the musculature. The submucous vessels take their origin from an exceedingly rich net-work which extends throughout the entire surface of the tongue. It is especially close toward the tip, the meshes becoming larger posteriorly, and that portion of it which lies posterior to the circumvallate papillæ is independent of that of the more anterior portions of the tongue. The vessels of the muscular portion of the organ are much less extensively developed and the efferent stems which pass from them early unite with those of the submucous net-work. These latter are quite numerous and for purposes of description may be arranged in four groups.

* Internat. Monatsschrift f. Anat. u. Physiol., 1900.

The first or *apical group* (Fig. 805) consists of from two to four stems which arise from the net-work at the tip of the tongue and pass downward and backward, half of them lying on one side of the frenum and half on the other side. They follow at first the anterior border of the genio-hyo-glossus muscle and then pass upon the outer surface of that muscle and are continued downward and backward, either external or internal to the hyo-glossus, until they reach the greater cornu of the hyoid bone, just below the attachment of the stylo-hyoid. They then cross obliquely over the outer surface of the greater cornu, and are continued down the neck along the outer border of the omo-hyoid muscle to open into one of the inferior deep cervical nodes situated upon the jugular vein just above the point where it is crossed by the omo-hyoid muscle. Sometimes an additional apical stem passes down the frenum in company with those just described, but continues on downward to perforate the mylo-hyoid muscle and terminate in one of the submental nodes.

A second or *lateral group* consists of a number of vessels which emerge from the net-work along the borders of the tongue (Fig. 804). There are from eight to twelve stems in this group on either side, and all are at first directed almost vertically downwards, a few, three or four, passing laterally to the sublingual gland and the rest medial to it. The former continue their downward course, perforate the mylo-hyoid muscle, and terminate in the submaxillary nodes, while the others take a course obliquely downward and backward, and, passing some upon the median and others upon the lateral surface of the hyo-glossus muscle, terminate in the superior deep cervical nodes and especially in one situated a little above the level of the bifurcation of the common carotid artery. This node, on account of its relations to these lingual stems, has been termed the *principal node of the tongue* (Fig. 805).

FIG. 804.



Lymphatics of dorsum and margins of tongue. (*Küttner*.*)

A third or *basal group* takes its origin from the dense portion of the submucous net-work which surrounds the circumvallate papillæ and the foramen cæcum. Four stems issue from the net-work in the neighborhood of the median line, and two on each side more laterally. The median stems pass at first directly backward and then bend outward in the glosso-epiglottidean folds, two on either side, and join the lateral stems beneath the tonsils. The lateral stems, which drain the regions of the lateral circumvallate papillæ, the foliate papillæ, and the glandular region of the tongue, are directed backward towards the lower border of the tonsil, and, after being joined in that situation by the median stems, they pass deeply to terminate in the superior deep cervical nodes.

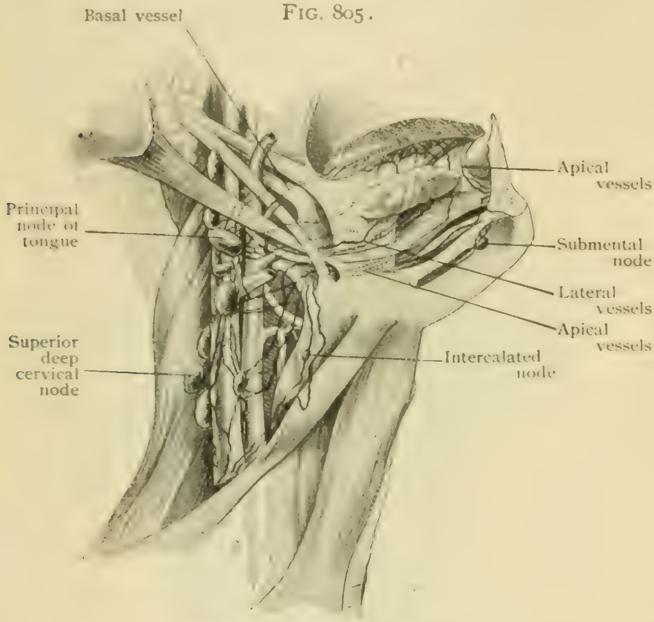
Finally, a fourth or *median group* arises from the net-work of the median portion of the tongue, anterior to the circumvallate papillæ. These stems are five or six in number, and pass at first directly downward through the substance of the tongue and through the interval which separates the two genio-hyo-glossal muscles. One or two of them then continue in their downward course and pass, in some cases

* Beiträge f. klin. Chirurgie, Bd. xxi., 1895.

to the right and in some to the left, between the genio-hyo-glossus and the genio-hyoid muscles, perforate the mylo-hyoid, and terminate in the submaxillary nodes. The remaining three or four stems pass backward along the mylo-hyoid muscle and, emerging at its posterior border, pass to the superior deep cervical nodes.

From this account it will be seen that four different groups of nodes stand in relation to the lymphatics of the tongue. (1) The submental nodes receive a stem from the tip; (2) the submaxillary nodes receive stems from the marginal and central regions; (3) the superior deep cervical nodes receive stems from the marginal, central, and basal regions; and (4) the inferior deep cervical nodes receive a stem from the apical region. In addition it may be mentioned that many of the stems have upon their course one or more of the small "intercalated" lingual nodes (page 948). Special importance, however, attaches to that superior deep cervical node already mentioned as occurring at about the level of the bifurcation of the common carotid artery, on account of the numerous afferents it receives from the tongue.

FIG. 805.



Lymphatics of tongue. (*Poirier.**)

The lymphatics of the *floor of the mouth* have essentially the same terminations as those of the tongue. The stems which arise from its anterior half pass with the stems from the tip of the tongue to the inferior deep cervical nodes, while from its entire surface stems pass to the submaxillary and superior deep cervical nodes.

The Palate, Pharynx, and Tonsils.—The lymphatics of the *hard palate* form a fine net-work in the superficial portions of the mucous membrane and are continuous laterally with those of the upper gum. They empty into several stems which pass backward in the median line of the palate and at about the level of the last molar teeth bend outward to the right and left, and, passing in front of the anterior pillars of the fauces, pierce the superior constrictor of the pharynx to terminate in those superior deep cervical nodes which are situated on the internal jugular vein above the level at which it is crossed by the posterior belly of the digastric muscle.

The net-work of the *soft palate* is exceedingly close and especially so in the uvula, which in a successful injection of the lymphatics may treble its volume, becoming exceedingly turgid (Sappey). Stems emerging from the net-work pass toward both surfaces of the palate, those lying below the upper surface passing backward and outward to join the stems from the nasal mucous membrane just below the orifice of the Eustachian tube, whence their course is similar to that of the nasal stems. Some of them pass upward and backward to perforate the superior constrictor of the pharynx and terminate in the lateral retropharyngeal nodes, while others descend beneath the mucous membrane covering the posterior pillars of the fauces and, after perforating the superior constrictor, terminate in the upper nodes of the superior deep cervical group.

* Gazette hebdomadaire, 1902.

The lymphatics of the *tonsil*, which resemble those of the soft palate in their abundance, pass with the stems from the basal region of the tongue to the superior deep cervical nodes.

Those of the *pharynx* are also abundant, especially above (Fig. 799). The stems which arise from the roof and upper part pass principally to the retro-pharyngeal nodes, although some reach the superior deep cervical nodes directly by following the course of the ganglionated cord. The stems which have their origin in the lower part of the pharyngeal net-work pass downward toward the larynx and unite with its vessels to be distributed to the superior deep cervical nodes as far down as opposite the level of the second or third tracheal ring.

Practical Considerations.—*The Lymph-Nodes of the Head.*—The lymphatics of the *scalp* pass from the plexus of fine radicles on the vertex into the suboccipital (occipital), mastoid (postauricular), parotid (preauricular), and superficial cervical nodes, and a few—from the frontal region—into the submaxillary node, into one or the other of which infection may be carried from any portion of the scalp.

The *suboccipital nodes*—one to three on each side—lie on a line drawn from the junction of the upper and middle thirds of the ear to the inion and about two inches external to that point. They are often enlarged as a result of wounds or irritation of the occipital and postauricular portion of the scalp and—especially in neglected children—as a consequence of eczema affecting the skin back of the ear. The close relation of the node to the great occipital nerve, on which it usually lies, gives rise to marked tenderness on pressure, the nerve being compressed between the node and the bone. The source of infection of these nodes may be intracranial—*e.g.*, suppurative meningitis of the cerebellar fossa (Macewen).

The *posterior auricular* or *mastoid node*, found directly over the mastoid insertion of the sterno-cleido-mastoid, is likewise usually infected from the same scalp region. It may also be involved alone or together with the suboccipital and deep cervical nodes in localized tuberculous mastoiditis or even in tuberculous otitis media.

The *parotid nodes*, lying both in and upon the gland, receive lymph from and consequently may be infected by lesions of the scalp, the outer portion of the lids, the orbit, the cheeks, the nasal fossæ, the naso-pharynx, the external auditory meatus, the tympanum, or the temporo-mandibular joint. Chronic enlargement of these nodes, especially of the deeper ones in the substance of the gland and beneath the parotid capsule, may lead to a mistaken diagnosis of parotid tumor. Suppurative inflammation of these deeper nodes gives rise to a true parotid abscess, which, on account of the resistance of the strong parotid fascia, will be under great tension. Sloughing of the parotid tissue may occur. There will be shooting pains in the head, neck, and ear, from pressure on the branches of the trigeminus accompanying the facial, or on the auriculo-temporal and great auricular nerves. The contiguity of the temporo-mandibular joint—into which the abscess may open—makes movement of the lower jaw painful. The relative weakness of the capsule anteriorly and on its inner aspect causes the pus to travel forward towards the cheek, or inward towards the pharynx, following sometimes the pharyngeal process of the parotid and giving rise to a retropharyngeal abscess. Gravity and the cervical process of the parotid may conduct the pus into the neck.

The lymphatics of the *face* empty, the superficial set—accompanying the facial vein—into the parotid and submaxillary nodes; the deep set, with some of those of the orbit, palate, nasal fossæ, and upper jaw, are said to end in the *internal maxillary nodes* situated at the sides of the pharynx anteriorly. According to Leaf, these are only exceptionally present. Their involvement in infections spreading from the above regions may give rise to "latero-pharyngeal abscess," causing a swelling externally behind the angle of the mandible, and an inward projection of the pharyngeal wall posterior to the tonsil. The proximity of the internal carotid should be remembered, and the fact that an aneurism of that vessel has been opened under the impression that it was an abscess of this variety (page 747).

Some lymphatics from the chin and the mid-portion of the lower lip empty into the suprahyoid (submental) nodes lying on the mylo-hyoid between the two anterior bellies of the digastrics. Enlargement of these nodes may be distinguished

from a bursal tumor (thyro-hyoid) by the fact that the former is above, the latter below, the hyoid bone.

Enlargement of a *submaxillary node*, as of a parotid node, may, particularly if it lies within the sheath of the gland, be mistaken for a growth of the gland itself. The latter—as compared with the parotid—is, however, much less closely and firmly enveloped by its capsule, is more superficial, and is not in near relation to such important structures. On the other hand, the wide area which drains into the submaxillary nodes—the middle of the forehead and of the face, the inner portions of the lids, the mouth, pharynx, anterior portion of the tongue, gums and teeth of the lower jaw—renders them especially liable to pyogenic or tuberculous or syphilitic infection, or to secondary involvement in carcinoma of any of these regions—especially of the tongue or lower lip. In examining for enlargement of these nodes, the chin should be lowered so as to relax the depressors of the lower jaw and the deep cervical fascia and permit of more accurate palpation of the region. When these submaxillary nodes require removal for infectious or malignant disease, the salivary gland is often involved and must be removed with them. On account of its accessibility and the laxity of its capsular connections, enucleation of this gland is easily accomplished. The relation of the facial artery lying close to the upper part of its deep aspect—which it grooves—before crossing the jaw in front of the masseter muscle should be remembered.

The efferent vessels from all these nodes—suboccipital, mastoid, parotid, and submaxillary—enter into the superficial cervical nodes, the efferent vessels from which, in their turn, enter the deep cervical nodes (page 957). Extracranial lesions of an irritative kind will thus first show themselves in enlargement of the first mentioned groups; if the irritation is continued, the superficial cervical nodes will enlarge; and if it persists and is sufficiently severe, the deep cervical will also participate in the enlargement (Macewen). As the intracranial lymph-paths, having their origin in the cerebral pia mater and the choroid plexuses of the ventricles, pass out of the skull in company with the internal carotid and vertebral arteries and, lower, the internal jugular vein and empty into the deep cervical nodes, these latter are, theoretically, first affected by intracranial irritation. As they lie beneath the cervical fascia, their enlargement may not be early noticed. These variations in the seat of glandular swelling cannot, however, be relied upon as a basis for a positive differential diagnosis between intracranial and more superficial (extracranial) sources of irritation or infection.

THE LYMPHATICS OF THE NECK.

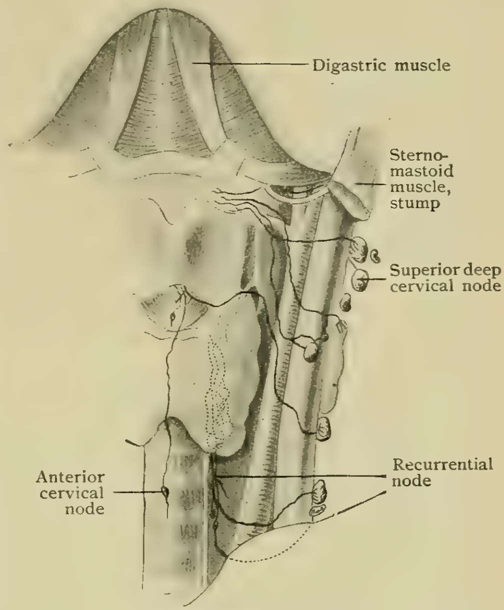
The Lymph-Nodes.

The principal group of nodes in the neck region is that which is situated along the course of the internal jugular vein, forming the **jugular plexus** (**plexus jugularis**). It consists of a variable, but usually large, number of nodes and is interposed in the pathway followed by the entire lymphatic system of the head and neck. It is practically a continuous chain of nodes, extending the entire length of the neck, but for convenience in description it is convenient to regard the nodes as forming two subgroups which are named the *superior* and *inferior deep cervical nodes*. In addition to these some smaller groups occur more superficially, forming what are termed the *superficial cervical nodes*, so that altogether there are three main groups of nodes in the cervical region.

The **superficial cervical nodes** (**lymphoglandulae cervicales superficiales**) may conveniently be divided into two subgroups, both of which are composed of rather small and somewhat inconstant nodes. The *external jugular nodes*, as their name indicates, are situated along the course of the external jugular vein, and consequently rest upon the outer surface of the sterno-cleido-mastoid muscle. They occur a little below the lower extremity of the parotid gland (Fig. 796), and are usually two or three in number, one or two additional nodes sometimes being present at a somewhat lower level. They receive *afferents* from the pinna of the ear and from the parotid region, and their *efferents* pass over the anterior border of the sterno-cleido-mastoid to open into the superior deep cervical nodes.

The second subgroup is that of the *anterior cervical nodes*, which are both variable and inconstant and are situated beneath the depressor muscles of the hyoid bone, resting upon the anterior surface of the larynx and on the anterior and lateral surfaces of the trachea. Those which rest upon the trachea are somewhat more constant than the others, but like them they are usually small and are therefore likely to be overlooked in normal conditions. The more lateral members of the series, from three to six in number, are arranged in a chain which follows the course of the recurrent (inferior) laryngeal nerve and are sometimes spoken of as the *recurrential nodes.* The anterior cervical nodes receive *afferents* from the larynx and trachea, and their efferents pass to the lower superior deep cervical nodes.

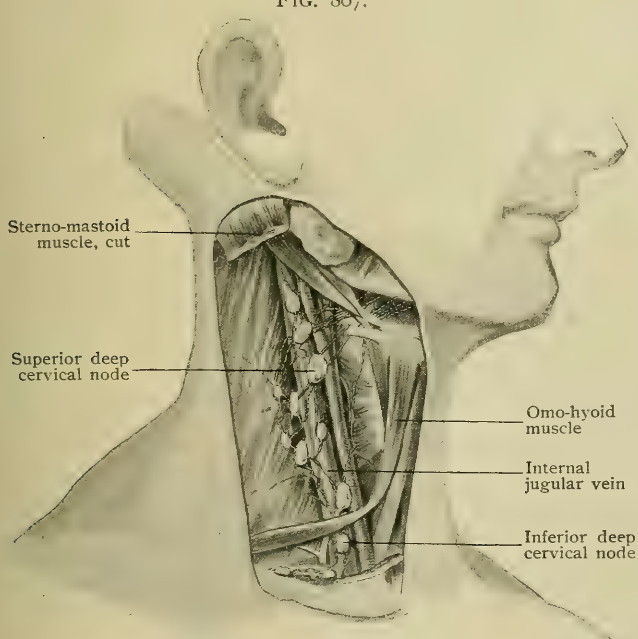
FIG. 806.



Anterior cervical and recurrential nodes and lymphatics of larynx. (*Most.**)

The **superior deep cervical nodes** (**lymphoglandulae cervicales profundae superiores**) vary from ten to sixteen in number, and extend along the course of the internal jugular vein from the tip of the mastoid process to the level at which the vein is crossed by the omo-hyoid muscle. They lie either directly upon the vein or slightly posterior to it, beneath the sterno-cleido-mastoid muscle, and are all united by numerous connecting stems so that they form a veritable plexus. Some of the nodes are exceedingly constant in position, one, especially, which receives numerous afferents from the lingual region and has therefore been termed the *principal node of the tongue*, occurring at about the level of the bifurcation of the common carotid artery, and a second is situated just above the omo-hyoid muscle. The *afferents* of the group are very numerous, and may be divided into two classes according as they take their origin in nodes belonging to other groups or come directly from the lymphatic net-works. Belonging to the first class and terminating in the more posterior nodes are the efferent stems for the posterior auricular and

FIG. 807.



Deep cervical lymph-nodes.

* Anatom. Anzeiger, Bd. xv., 1899.

occipital nodes, while in the more anterior nodes efferents from the retropharyngeal, parotid, submaxillary, submental, and superficial cervical nodes terminate.

Belonging to the second class and terminating in the more posterior nodes are (1) a vessel which descends directly from the occipital region of the scalp; (2) some stems from the posterior surface of the pinna; and (3) stems from the upper part of the back of the neck. To the more anterior nodes pass (1) the majority of the stems descending from the tongue; (2) stems from the nasal mucous membrane, the palate, and the upper portions of the pharynx; (3) stems from the cervical portion of the œsophagus; (4) the majority of the stems from the larynx and those which come from the cervical portion of the trachea, and (5) the stems from the thyroid gland.

The *efferents* from the lower nodes of the plexus pass partly to the inferior deep cervical nodes, and partly unite with the efferents of these to form the jugular trunk, which is described below.

The **inferior deep cervical nodes** (**lymphoglandulae cervicales profundae inferiores**), also termed the *supraclavicular nodes*, occupy the supraclavicular triangle of the neck, resting upon the scalene muscles and upon the trunks of the brachial plexus. They are fewer in number and, as a rule, smaller than the superior deep cervical nodes. In addition to the *afferents* from the superior nodes they receive (1) a stem which passes directly downward from the occipital region of the scalp along the posterior border of the sterno-cleido-mastoid muscle; (2) vessels from the integument and muscles of the lower portion of the neck; (3) vessels from the integument of the upper portion of the pectoral region; (4) occasionally some vessels from the arm which follow the course of the cephalic vein; (5) some efferents from the brachial groups of the axillary nodes; and (6) vessels which pass to the lower nodes of the left, rarely the right, side from the liver, ascending in the suspensory ligament of that organ, piercing the diaphragm, and following the course of the internal mammary vessels upward through the thorax.

Their *efferents* unite with some of those from the superior deep cervical nodes to form a single stem, the **jugular trunk** (**truncus jugularis**), which on the left side opens into the arch of the thoracic duct and on the right unites with the subclavian trunk to form the right lymphatic duct. Both the right and the left trunks, however, frequently open directly into the subclavian vein.

The Lymphatic Vessels.

The Integument and Muscles of the Neck.—The lymphatic stems arising from the subcutaneous and muscular net-works of the neck open into the posterior nodes of the superior deep cervical chain.

The Larynx and Trachea.—The lymphatic net-work of the larynx is very well developed over the greater portion of the mucous membrane and is especially rich in the regions of the false vocal cords and the ventricles. Over the true vocal cords, however, it is very feebly developed, and the entire net-work may therefore be regarded as consisting of two portions, one of which is situated above the level of the true cords and the other below them. The two portions are not, it is true, perfectly distinct, since they are connected by the feeble net-work of the true cords; but it has not been found possible to force an injection from one portion into the other and, furthermore, each portion gives rise to a special set of efferent stems.

The stems which arise from the upper net-work are from three to six in number on each side, and make their exit from the larynx through the lateral portions of the thyro-hyoid membrane, in close proximity to the superior laryngeal artery (Fig. 806). They then pass outward to the anterior nodes of the superior deep cervical chain, some opening into the nodes situated in the neighborhood of the bifurcation of the common carotid artery, while others, bending downward, terminate in lower nodes.

The stems from the lower net-work pass in two directions; a few small ones perforate the crico-thyroid membrane near the median line, while the rest are directed posteriorly and make their exit below the lower border of the cricoid cartilage. The anterior stems pass partly to an anterior cervical node situated usually in the median

line between the two crico-thyroid muscles, another descends over the isthmus of the thyroid gland to terminate in one of the nodes which rest upon the anterior surface of the trachea, while one or two pass outward along the upper border of the lobes of the thyroid gland and then descend to terminate in one of the superior deep cervical nodes situated about opposite the middle of the sterno-cleido-mastoid muscle. The posterior stems, which are from three to six in number, after making their exit from the larynx, follow the course of the recurrent laryngeal nerves and terminate in the recurrential nodes situated in the course of those nerves, some of the stems frequently anastomosing to form a plexus which descends along the vagus nerve and may be followed, in some cases, to the inferior deep cervical nodes.

The net-work of the trachea is formed of delicate and slender vessels arranged so as to form elongated meshes, and the stems which arise from it emerge from the lateral surfaces of the trachea, passing between the tracheal cartilages. Those from the upper part of the trachea pass to the recurrential nodes, while the lower ones pass to the bronchial nodes situated in the neighborhood of the bifurcation of the trachea.

The Thyroid Gland.—The lymphatic stems from the thyroid gland pass for the most part to the superior deep cervical nodes, following the course of the superior thyroid artery, some of them, however, passing at first directly upward and coming into relation with an anterior cervical node situated upon the crico-thyroid membrane. Those which arise from the lower border of the isthmus and from the neighboring portions of the lobes are directed downward, and terminate in the anterior cervical nodes which are situated upon the anterior surface of the trachea and in the recurrential nodes.

The Œsophagus.—The cervical portion of the œsophagus will be considered together with its thoracic portion (page 971).

Practical Considerations.—*The Lymph-Nodes of the Neck.*—1. The *superficial cervical nodes*—not invariably present—are found over the sterno-mastoid, along the external jugular vein, between the deep fascia and the platysma, and may be enlarged in various affections of the external ear and of the skin of the face and neck, or consecutively to infections of the suboccipital (occipital), mastoid (post-auricular), parotid (preauricular), or submaxillary nodes. Those found posteriorly near the anterior border of the trapezius muscle enlarge early in the secondary stage of syphilis and, on account of their accessibility for palpation, are then of diagnostic value. 2. The *deep cervical nodes* are divisible, for convenience, into two groups: (*a*) an upper group, situated about and above the bifurcation of the common carotid artery and the upper part of the internal jugular vein, some of which lie partly beneath the posterior edge of the sterno-mastoid and partly projecting into the posterior cervical triangle; (*b*) a lower group, found near the lower portions of the internal jugular, external jugular, subclavian, and transverse cervical veins, and lying almost completely beneath the sterno-mastoid. At the root of the neck this group is continuous externally with the subclavian and axillary, and internally with the mediastinal nodes. All these deep cervical nodes lie in or beneath the deep fascia and receive the efferent vessels from the superficial nodes (and thus from their tributaries mentioned above) as well as all other lymphatics of the head and neck—retropharyngeal, suprahyoid, etc.—that do not directly communicate with the superficial group.

The deep cervical nodes are accordingly found to be inflamed or enlarged consecutively to a great variety of conditions,—*e.g.*, eczema, wounds or ulcers of any portion of the scalp or face, dental caries, alveolo-dental abscess, pharyngeal or buccal or tonsillar inflammation or ulceration, fissures or ulcers or carcinoma of the tongue, otitis (external or medial), rhinitis, hordeolum, labial herpes or chancre or epithelioma. They may also be enlarged—though with great rarity—from primary carcinoma and—less rarely—from lympho-sarcoma or from Hodgkin's disease. Furthermore, various intracranial conditions may be followed by involvement of the cervical nodes, both superficial and deep. In most cases the infection comes from the same side of the head, face, or neck, as the enlarged glands, but occasionally the original lesion is on the opposite side.

Swellings of this deep chain of glands—especially of those beneath the sterno-mastoid—may be present without being distinctly palpable, and are apt, in any case severe enough to come to operation, to involve many more nodes than were previously suspected.

One node of the upper group lies behind the posterior belly of the digastric in the angle between the internal jugular and facial veins. Leaf has suggested that it be called the "jugulo-digastric" node. In some affections of the tonsil and of the base of the tongue, it enlarges and projects in front of the anterior border of the sterno-mastoid, its contents being about half an inch below and somewhat internal to the angle of the jaw.

Other glands of this group, which are very constant in position, lie over the insertion of the splenius capitis under cover of the upper end of the sterno-mastoid and surround the spinal accessory nerve before it perforates the latter muscle. Enlargement of these glands would compress the nerve against the transverse process of the atlas (Leaf).

The retropharyngeal nodes lie in the space of that name (page 552), about opposite the axis, on the rectus capitis anticus major and to the inner side of the glosso-pharyngeal nerve where it curves around the lower border of the stylo-pharyngeus. They communicate with the upper group of the deep nodes. They may be enlarged from infection through the overlying mucosa, as they are in close relation to the buccal portion of the pharynx, which, on account of its many crypts or recesses, the large amount of adenoid tissue present, its relatively direct exposure to mechanical injury and to the current of inspired air (drying it, reducing its temperature, and possibly conveying microbic irritants), is especially susceptible to inflammation. They may also enlarge as a result of caries of the bodies of the cervical vertebræ. In either case, there may be pharyngeal and tonsillar pain, ear-ache, and other evidence of glosso-pharyngeal irritation. If suppuration occurs, a fluctuating swelling appears which pushes the posterior wall of the pharynx forward (the retropharyngeal connective tissue being lax to permit of the free movement of the pharynx during deglutition), depresses the soft palate, and causes dysphagia; or, if lower, causes dysphonia and dyspnœa by obstructing the laryngeal opening. Such an abscess may gravitate along the œsophagus into the mediastinum and may even reach the diaphragm; or it may extend laterally behind the parotid and great vessels to the side of the neck, or, reaching the cords of the brachial plexus, may be conducted by them to the posterior cervical triangle or down into the axilla. Such an abscess should not be left to spontaneous evacuation, on account of the danger of its extension in these directions, or—if the abscess should suddenly burst into the pharynx—of suffocation or of septic pneumonia if the pus entered the air-passages. It may be opened through the mouth, in the mid-line of the pharynx (the head being bent over so that the pus would not run toward the glottis), or externally by an incision along the posterior margin of the sterno-mastoid, the great vessels being pushed forward as the wound is deepened.

The lower group of deep cervical nodes enlarge most frequently consecutively to infection or disease of the upper group. They also receive the lymphatics from the supraspinous fossa which follow the suprascapular artery, and those from the upper part of the deltoid. Those that lie at the very base of the neck, in the sub-clavian triangle, or on the omo-hyoid muscle, are not uncommonly affected in the latter stages of mammary carcinoma (page 2035). They are continuous with the axillary nodes, while those to their inner side—lying on the levator anguli scapulæ and scalenus medius just external to the internal jugular vein—are also often involved in the upward extension of cancer. Both sets communicate with the mediastinal nodes. On the left side they are in close proximity to the thoracic duct. The branches of the cervical plexus pass among the nodes of this deep cervical group.

In cases of chronic inflammation and enlargement of these nodes they will usually be found adherent to the internal jugular vein, which is in close relation to most of them. As the majority of them lie beneath the sterno-cleido-mastoid, that muscle will often have to be divided either partially or completely in operations for their removal. Certain cysts, in most cases congenital, usually subcutaneous but with deep prolongations into the intermuscular spaces, are found in the neck, and are believed

to be of lymphatic origin, because (*a*) they are often associated, and sometimes anatomically connected with other congenital defects of the lymphatic system, such as macroglossia (cavernous lymphangioma of the tongue) and macrocheilia (labial lymphangioma); and (*b*) they are in communication with the lymphatic trunks (Rolleston).

THE LYMPHATICS OF THE UPPER EXTREMITY.

The Lymphatic Nodes.

The lymphatic nodes of the arm are for the most part confined to its upper portions, the principal group occurring in the axilla and consisting of a considerable number of nodes united by connecting stems to form a *plexus axillaris*. A few scattered nodes also occur in the brachial region and some are occasionally to be found in the antibrachium, but they are entirely lacking in the hand. An especial interest attaches to the axillary nodes on account of the extensive area from which they receive afferents, for, in addition to almost the entire lymphatic drainage of the arm, they also receive the vessels from the anterior and lateral thoracic walls, from the mammary gland, and from the scapular region. The brachial and antibrachial nodes, on the other hand, are rather to be regarded as "intercalated" nodes interposed in the course of certain of the lymphatic vessels; some of them lie superficial to the deep fascia, while others are situated more deeply along the course of the principal blood-vessels, and, consequently, it is convenient to divide them into two sets according as they are superficial or deep.

The **superficial brachial nodes** (**lymphoglandulae cubitales superficiales**) are arranged in two principal groups. One of these rests upon the brachial fascia immediately over the internal condyle of the humerus, and may be termed the *epitrochlear group* (Fig. 809). It consists of from one to four nodes, of which one, the lowest of the group, is especially constant and is termed the *epitrochlear node*. The remaining nodes, if present, are situated along the course of the basilic vein, one frequently lying almost in the median line of the arm a short distance above the bend of the elbow. The *afferents* of the epitrochlear nodes are the superficial vessels of the forearm and hand, especially those which pass upward along the ulnar border of the forearm; their *efferents* pass upward along the basilic vein and join the deep vessels where the basilic vein dips down to join the brachial.

A second group, which may be termed the *delto-pectoral group*, consists of from one to four nodes situated along the course of the cephalic vein, in the groove between the deltoid muscle and the clavicular portion of the pectoralis major (Fig. 809). They are not always distinguishable and are usually quite small. They are interposed in the course of the delto-pectoral lymphatic stem which passes upward in the groove and opens into the subclavicular group of axillary nodes or occasionally into the inferior deep cervical nodes.

The **deep brachial nodes** sometimes include some small nodes occurring on the lymphatic stems which accompany the ulnar and radial blood-vessels, but these nodes are relatively inconstant. Of more frequent occurrence is a group of two or three small nodes (**lymphoglandulae cubitales profundae**) which occur upon the stems accompanying the brachial artery and are situated at about the middle part of its course. Their *afferents* are the deep lymphatics of the forearm and their *efferents* pass upward to terminate in the humeral nodes of the axillary group.

The **axillary nodes**, which are embedded in the areolar tissue occupying the axillary space, vary in number from sixteen to thirty-six. Some of them are usually of considerable size, especially in those cases in which their number approaches the lower limit mentioned, for it is a general rule that the size of the nodes in any group is inversely proportional to their number; but it seems probable that in addition to those which may be observed macroscopically, exceedingly small ones, approaching microscopic size, also occur, and that these, under pathological conditions or after removal of the larger ones, may increase in size and form additional or new foci of infection.

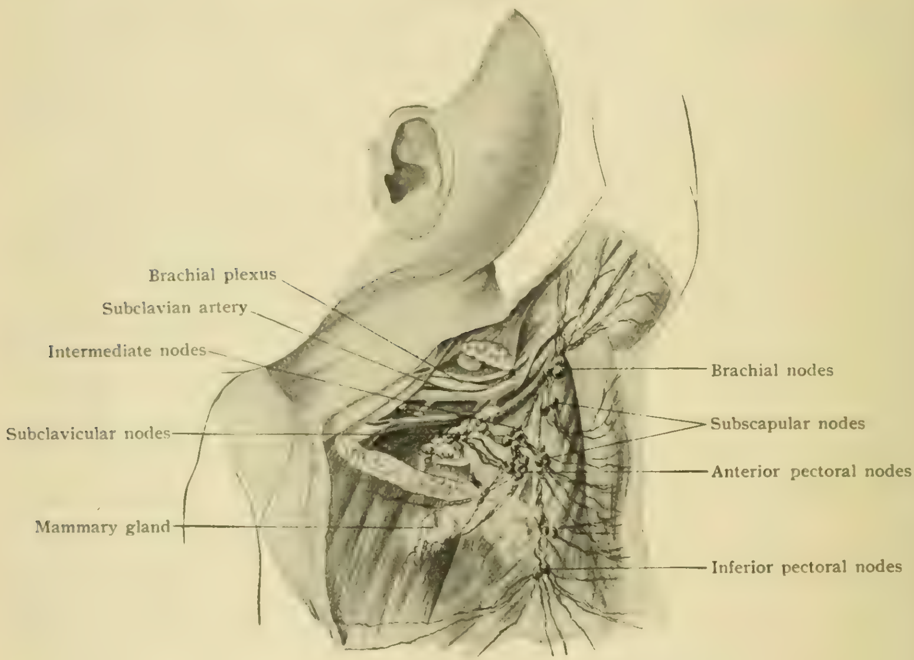
Although united by connecting stems to form a plexus, the axillary nodes may be divided, according to their position and the source from which their afferents come, into a number of more or less distinct subgroups (Figs. 808, 814), and of

these, four are terminals for lymphatic stems coming from the arm and the thoracic walls, while two others form relays between these terminal nodes and the subclavian trunk by which the lymph from the entire axillary plexus is conveyed to the right lymphatic duct or to the arch of the thoracic duct.

1. The *brachial subgroup* is composed of a number of usually large nodes, arranged in a chain along the axillary vein, for the most part along its inner surface, although a node is to be found behind it, between it and the subscapular muscle. The *afferents* of this group come from the arm and include almost the entire set of collecting stems from that region, only one of them, that which accompanies the cephalic vein, passing to another group. Their *efferents* pass partly to the intermediate subgroup of the axillary plexus, partly to the subclavicular subgroup, and partly to the lower nodes of the inferior deep cervical group.

2. The *anterior pectoral subgroup* is composed of two or three usually small nodes situated over the second and third intercostal spaces, beneath the lower

FIG. 808.



Axillary lymph-nodes, new-born child. (*Oelsner*.*)

border of the pectoralis major muscle and anterior to the long thoracic artery. They receive *afferents* from the integument of the anterior surface of the thorax, from the pectoral muscles, and from the mammary gland. Their *efferents* pass partly to the intermediate and partly to the subclavicular subgroup of the axillary nodes.

3. The *inferior pectoral subgroup* is composed of two or three small nodes, situated either upon or posterior to the long thoracic artery over the fourth and fifth intercostal spaces or even higher. They receive their *afferents* mainly from the integument of the lateral wall of the thorax and from the subjacent muscles, and their *efferents* pass to the nodes of the intermediate subgroup.

4. The *subscapular subgroup* (**lymphoglandulae subscapulares**) consists of a chain of six or more nodes situated along the course of the subscapular artery, and, in addition, includes two or three nodes which rest upon the dorsal surface of the scapula in the groove between the teres major and minor muscles. The *afferents*

* Archiv f. klin. Chirurgie, Bd. lxiv., 1901.

come from the integument and muscles of the lower part of the neck, from the dorsal surface of the thorax, and from the scapular region ; the *efferents* pass mainly to the nodes of the intermediate subgroup.

5. The *intermediate subgroup* consists of a number of rather large nodes imbedded in the adipose tissue which occupies the interval between the lateral wall of the thorax and the upper part of the long thoracic vein as it bends outward to open into the terminal part of the axillary vein. It receives *afferents* from all the terminal subgroups of the axillary plexus, and its *efferents* pass to the nodes of the subclavicular subgroup.

6. The *subclavicular subgroup* consists of from six to twelve nodes situated near the apex of the axillary space, partly beneath the pectoralis minor and partly above the upper border of that muscle. They constitute the final link in the axillary chain, since they receive as *afferents*, either directly or indirectly through the intermediate nodes, the efferents from all the other subgroups. Their *efferents* unite to form a trunk of considerable size, the **subclavian trunk** (truncus subclavius), which, from its origin opposite the first intercostal space, passes almost vertically upward over the subclavian vein to open into it near its junction with the external jugular, or else to unite with the jugular trunk on the right side or to open into the arch of the thoracic duct on the left side. In addition to this principal termination one or more of the subclavicular efferents usually pass to one of the lower nodes of the inferior deep cervical group.

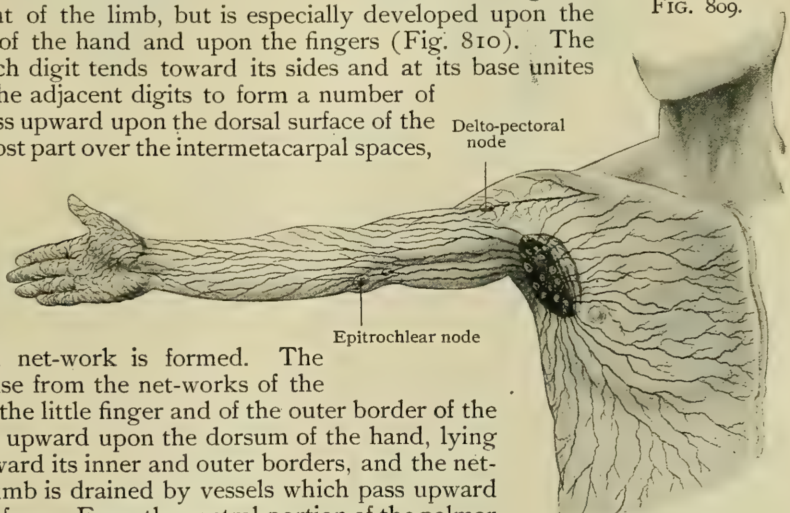
The independent termination of the subclavian trunk in the subclavian vein is probably the most frequent arrangement, but the exact position of its junction with the vein is variable. Most frequently it empties at the angle formed by the junction of the subclavian and internal jugular veins, but it may terminate upon the superior surface of the subclavian vein some distance (1 cm.) away from the angle, and quite frequently it opens upon the anterior surface of the vein, or, in rarer instances, upon its posterior surface. Not unfrequently two or even more subclavian trunks occur, and in such cases one may unite with the jugular trunk, or, if on the left side, open into the arch of the thoracic duct, while the other terminates directly in the vein.

The Lymphatic Vessels.

The lymphatic vessels of the upper limb are divisible into two groups according as they lie superficial to or beneath the deep fascia.

The **superficial vessels**, which are far more numerous than the deep ones, have their origin in the subcutaneous net-work which occurs throughout the entire extent of the limb, but is especially developed upon the palmar surface of the hand and upon the fingers (Fig. 810). The net-work of each digit tends toward its sides and at its base unites with those of the adjacent digits to form a number of stems which pass upward upon the dorsal surface of the hand, for the most part over the intermetacarpal spaces, although abundant anastomoses occur between the vessels of neighboring spaces so that an open dorsal net-work is formed. The stems which arise from the net-works of the inner border of the little finger and of the outer border of the index also pass upward upon the dorsum of the hand, lying respectively toward its inner and outer borders, and the net-work of the thumb is drained by vessels which pass upward on its dorsal surface. From the central portion of the palmar net-work some small stems pass deeply, penetrating the palmar aponeurosis to join the deep lymphatic vessels, but its remaining portions radiate in all directions to join the stems of the dorsal net-work. Thus, the distal portions of the net-work converge

Fig. 809.



Superficial lymphatic vessels of upper limb; semidiagrammatic. (Based on figures of *Sappey*.)

toward the webs of the fingers and pass dorsally to join the stems which pass upward over the intermetacarpal spaces; the inner portions pass over into a number of small stems which curve around the inner border of the hand to join the stems coming from the little finger; the outer portions similarly empty into the stems coming from the outer surface of the index finger and from the thumb; while the proximal portions give rise to a number of stems which pass upward along the anterior surface of the forearm. The arrangement, indeed, is very similar to that followed by the veins.

At the wrist, then, there are a considerable number (about thirty, more or less) of longitudinal stems which are arranged in two groups, one of which is dorsal and the other ventral (Figs. 810, 811). The former consists of the stems which drain the digital net-works and the distal and lateral portions of the palmar net-work, while the latter is formed of stems arising from the proximal portion of the palmar net-work. As they ascend the arm these stems receive afferents from the sub-

FIG. 810.

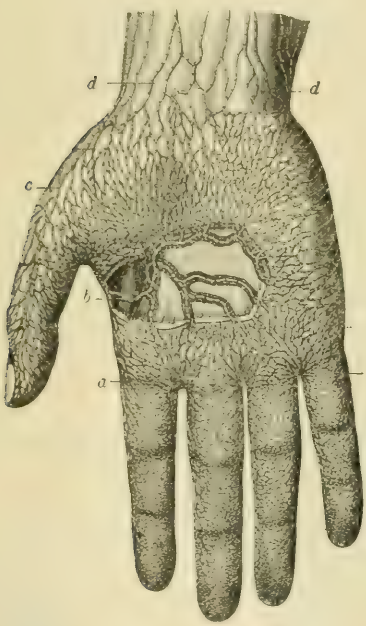
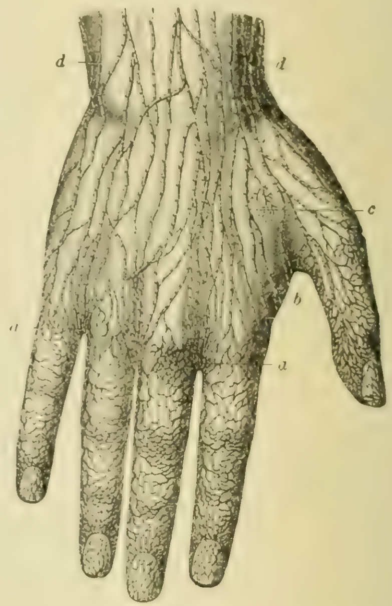


FIG. 811.



Lymphatics of hand: Fig. 810, palmar, Fig. 811, dorsal surface. Superficial digital net-works (*a*) empty at bases of fingers into larger stems (*b*, *c*), which are tributary to trunks on forearm (*d*); superficial palmar vessels communicate (Fig. 810, *b*) with deeper lymphatics. (*Sappey*.*)

cutaneous net-work of the forearm, and at the same time anastomose with one another, so that their number diminishes gradually as they ascend, until, at about the middle of the brachium, they are reduced almost to half the original number. As they approach the elbow (Fig. 809), the stems of the dorsal group divide into two sets, which curve forward, one around the outer border and the other around the inner border of the forearm, so that above the elbow all the principal stems are situated upon the anterior (ventral) surface of the arm, an arrangement which again recalls that presented by the veins.

Just above the bend of the elbow one or two of the inner stems pass into the epitrochlear nodes (Fig. 809), whose efferents pierce the brachial fascia to empty into the deep brachial lymphatics, but the majority of the remaining stems pass directly upward along the anterior surface of the brachium to terminate above in the brachial nodes of the axillary plexus. The most external stem follows, however, a different course (Fig. 809), accompanying the cephalic vein along the groove between the deltoid and pectoralis major muscles; after traversing the delto-pectoral

* Description et iconographie des vaisseaux lymphatiques, 1874.

nodes it perforates the costo-coracoid membrane and terminates in one of the subclavicular nodes or, more rarely, follows the course of the jugulo-cephalic vein over the clavicle and terminates in one of the lower inferior deep cervical nodes. From the net-work of the posterior surface of the brachium a number of small stems arise and pass obliquely upward, those lying towards the outer border of the arm curving around it to join the outer main stems, while the inner ones partly join the inner main stems and partly terminate in the subscapular nodes along with the vessels from the posterior surface of the shoulder.

The **deep lymphatics of the arm** are much less numerous than the superficial ones and follow the courses of the main blood-vessels, usually corresponding in number with the venæ comites. They occur in company with the radial, ulnar, anterior and posterior interosseous, and brachial vessels.

The *radial lymphatics* are formed by the union of two stems, one of which follows the course of the main stem of the artery from the deep palmar arch, while the other accompanies the superficial volar artery from the superficial arch. They come together, usually a short distance above the wrist-joint, to form two stems which pass upward along the artery and may traverse one or two small and inconstant nodes. They terminate by uniting with the ulnar stems to form the brachial lymphatics.

The *ulnar lymphatics* are also formed by the union of two stems, which accompany the deep and superficial branches of the ulnar artery. They accompany the ulnar artery up the forearm, occasionally traversing one or two small nodes, and, near their union with the radial stems below the bend of the elbow, they receive the stems which accompany the anterior and posterior interosseous arteries.

The *brachial lymphatics* are two in number and are formed by the union of the radial and ulnar stems. They accompany the brachial artery, traversing three or four nodes in their course and receiving the efferents of the epitrochlear nodes, or, these failing, the inner stems of the forearm. They terminate in the brachial nodes of the axillary plexus, especially in one which usually lies between the axillary vein and the subscapular muscle.

Practical Considerations.—*The Lymph-Nodes of the Axilla and Upper Extremity.*—The palm has relatively few large lymphatics (as it has few superficial nerves and blood-vessels); hence wounds of the fingers or of the dorsum of the hand, where the lymphatics are of larger size, are more commonly followed by lymphangitis than are wounds of the palm. Nodes are occasionally found along the course of the arteries of the forearm and arm, but are inconstant and not of great practical importance. One or two beneath the deep fascia on the flexor surface of the elbow and on a level with the internal condyle or an inch or two above it, are less variable and are sometimes palpably enlarged in syphilis at the time of the early general adenopathy.

The axillary nodes will be almost sufficiently described in relation to the subject of mammary cancer (page 2035). Further reference to them will be found in the description of the axilla (page 581).

These nodes may be the primary seat of lympho-sarcoma, may be the subject of tuberculous or syphilitic enlargement, and are constantly infected after septic wounds of the hand, forearm, or arm, and less frequently from wounds in the remaining areas which drain into them, viz., the cervical region over the trapezius muscle, the dorsal region, the lumbar region as far down as the level of the iliac crest, the abdominal region above the umbilicus, and the front and sides of the thoracic region. Their progressive enlargement widens the axilla, renders it more shallow by pushing its floor downward, makes the anterior fold prominent, and increases the space between the outer border of the scapula and the thoracic wall. Axillary abscess commonly originates in these nodes, consecutively to sepsis elsewhere, as in the regions mentioned, or after shoulder-joint suppuration, or mammary infection, or caries of an upper rib. Such an abscess will produce rapidly the same phenomena as those caused by a growth. It may make its way behind the clavicle into the supraclavicular fossa by following the cords of the brachial plexus, or may gravitate down the arm along the course of the vessels. It cannot come directly forward on account of the pectoral muscles and clavi-pectoral fascia, or downward on account of the

axillary fascia, or backward by reason of the attachment of the serratus magnus to the scapula, or outward or inward because of the upper limb and the wall of the thorax.

It should be opened half way between the anterior and posterior folds near the inner or thoracic wall.

THE LYMPHATICS OF THE THORAX.

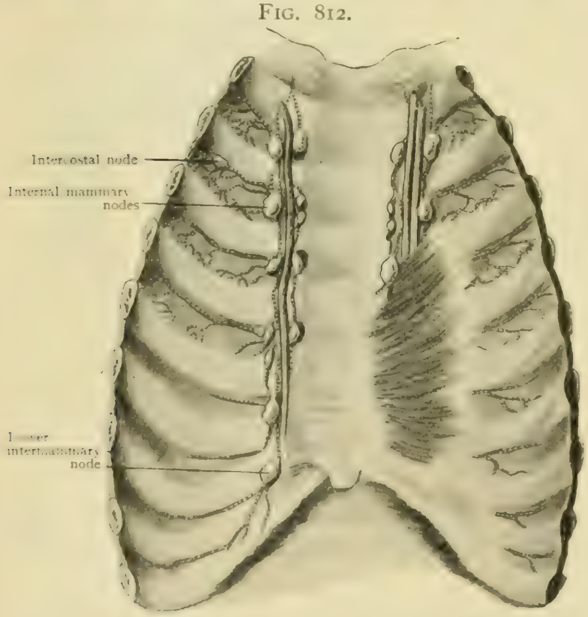
The Lymph-Nodes.

Certain of the nodes which have been described as belonging to the axillary plexus, namely, those forming the anterior and inferior pectoral subgroups, might well be considered as belonging to the thoracic set, since their afferents drain the anterior and lateral walls of the thorax. On account of their situation, however, as well as their intimate connection by efferents with the intermediate and subclavicular axillary nodes, they are more conveniently classed with the axillary set.

The remaining thoracic nodes may be divided into two sets according as they occur in connection with the thoracic walls, *parietal* nodes, or with the viscera, *visceral* nodes. Of the parietal nodes there are two principal groups.

The **sternal or internal mammary nodes** (**lymphoglandulae sternales**) form two chains which extend upwards upon the inner surface of the anterior thoracic wall, along the course of the internal mammary blood-vessels (Fig. 812). They vary in number from four to ten, and are situated at the anterior or sternal ends of three or more of the upper intercostal spaces, resting upon the internal intercostal muscles and being covered, so far as the lower members of the group are concerned, by slips of the triangularis sterni. Their *afferents* come from the anterior diaphragmatic nodes, from the upper portions of the rectus abdominis, from the anterior portions of the intercostal muscles, from the integument over the sternum and costal cartilages, and, to a certain extent, from the mammary glands. Since the nodes are arranged in the form of a chain, the *efferents* from the lower members of the series are afferents for the higher ones; the terminal efferents usually unite to form a single stem which joins the efferents of the anterior mediastinal and bronchial nodes to form the broncho-mediastinal trunk (page 968).

Fig. 812.



Lymph-nodes of anterior thoracic wall, viewed from behind. (Based upon figure of *Poirier and Cunéo*.*)

The **intercostal nodes** (**lymphoglandulae intercostales**) are situated along the courses of the intercostal arteries, the principal and most constant members of the series being situated towards the posterior extremities of the intercostal spaces. Some nodes which occur in the lateral portions of the spaces are inconstant and always small; they are usually situated, when present, at the point where the intercostal arteries give off their lateral perforating branches.

The *afferents* of the intercostal nodes drain the posterior portions of the intercostal spaces. The *efferents* of the lower members of the series unite to form a stem which passes downward and terminates in the receptaculum chyli, while those from

* Poirier et Charpy: Traité d'anatomie humaine, Tome ii., 1902.

the nodes of the upper spaces are directed more or less medially to open into the thoracic duct.

The visceral nodes of the thorax may be arranged in three main groups, one consisting of the nodes situated in the anterior mediastinum, a second of those situated in the posterior mediastinum, and a third of those which occur in the neighborhood of the bifurcation of the trachea and along the bronchi.

The **anterior mediastinal nodes** (**lymphoglandulae mediastinales anteriores**) are arranged in two groups, one of which occurs in the lower and the other in the upper part of the mediastinum. The nodes of the lower group, termed the *diaphragmatic nodes*, are from three to four in number, and are situated upon the anterior part of the upper surface of the diaphragm, immediately behind the xiphoid process of the sternum ; their *afferents* come from the diaphragm and from the upper surface of the liver, and their *efferents* pass to the lower deep cervical nodes, following the course of the internal mammary vessels.

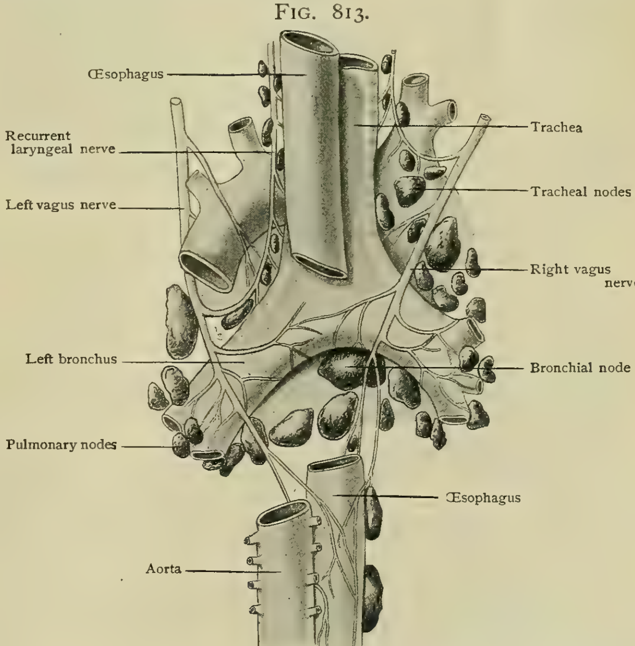
The upper group, that of the *cardiac nodes*, is composed of from eight to ten nodes situated upon the anterior surfaces of the arch of the aorta and the left innominate vein. They receive *afferents* from the anterior surface of the pericardium and thymus gland and from the sternal and bronchial nodes. Their *efferents* pass upward and unite with those from the bronchial nodes to form the broncho-mediastinal trunk (page 968).

The **posterior mediastinal nodes** (**lymphoglandulae mediastinales posteriores**), eight to twelve in number, are situated along the thoracic aorta in the posterior mediastinum. Their *afferents* come from the œsophagus, the posterior surface of the pericardium, and the upper surface of the liver, while their *efferents* open mainly into the thoracic duct, a few passing to the bronchial nodes.

Two or three small nodes which may be regarded as belonging to this group occur upon the convex surface of the diaphragm in the neighborhood of the opening for the inferior vena cava. They receive *afferents* from the diaphragmatic net-work and also from the superficial net-work of the upper surface of the liver.

The **bronchial nodes** (**lymphoglandulae bronchiales**) on account of their number and size are the most important of the thoracic nodes, and for the convenience of description they may be regarded as forming three subgroups (Fig. 813). One of these is formed by the *tracheal nodes* (**lymphoglandulae tracheales**), seven to ten in number and situated on either side of the lower part of the trachea. Those upon the right side are as a rule more numerous and larger than those on the left side, varying from the size of a pea to that of a bean in the normal condition. A second subgroup is that of the *bronchial nodes* proper, from ten to twelve in number and situated in the angle formed by the two bronchi. They are for the most part large, those beneath the right bronchus being usually larger and more numerous than

FIG. 813.



Tracheal and bronchial lymph-nodes, viewed from behind. (*Hallé*.*)

* Clinique médicale, Tome iv.

those below the left one. The third subgroup is formed by the *pulmonary nodes*, usually of small size and situated in the hilus of the lungs, between the larger divisions of the bronchi.

The *afferents* of the bronchial nodes are (1) from the lungs, (2) from the lower part of the trachea and from the bronchi, (3) from the heart, and (4) from the posterior mediastinal nodes. Their *efferents* may either pass as a number of stems to the thoracic duct or directly to the subclavian vein on the right side, but more frequently they unite to form a single stem, with which the stems coming from the sternal and anterior mediastinal nodes unite to form a single **broncho-mediastinal trunk** (**truncus bronchomediastinalis**), which passes upward toward the confluence of the internal jugular and subclavian veins. It either opens independently into the subclavian vein, which is the most usual arrangement, or else, on the right side, it unites with the subclavian and jugular trunks to form the right lymphatic duct or, on the left side, it unites with the subclavian trunk to open into the arch of the thoracic duct, into which it may also open directly.

The Lymphatic Vessels.

The **cutaneous lymphatics of the thorax** form a rich net-work extending throughout the subcutaneous tissue and being continuous above with the subcutaneous net-work of the cervical region and below with that of the abdomen. From the net-work of the anterior surface a considerable number of stems arise, which pass outward, the upper ones almost horizontally and the lower ones obliquely upward and outward, to terminate in the anterior pectoral nodes of the axillary plexus (Fig. 814). These stems form the principal path of the anterior thoracic drainage, but, in addition, some stems which arise from the upper portion of the net-work pass upward over the clavicle and terminate in some of the lower inferior deep cervical nodes, and from the portions of the net-work near the median line short stems perforate the intercostal spaces and terminate in the sternal nodes. Furthermore, it is to be noted that the net-works of either side are continuous across the median line over the surface of the sternum, and there may consequently be a certain amount of crossing in the lymph flow, that coming from the more median portions of the net-work of the right half of the anterior thoracic wall, for instance, terminating in the left axillary nodes. These decussating paths are, however, of comparatively little importance except in cases of stoppage of the normal flow to the axillary nodes of the same side, and in such cases a collateral drainage may also be established for the lower portion of the thoracic walls through the abdominal lymphatics to the inguinal nodes.

Upon the lateral portions of the thorax the net-work gives rise to some half dozen stems which pass upwards to terminate in the inferior pectoral nodes of the axillary plexus, and from the net-work of the posterior thoracic wall about ten or twelve main stems arise which converge laterally to terminate in the subscapular group of the axillary plexus. As was the case in the anterior net-work, so in the posterior net-work some stems from the upper portions of the dorsal net-work pass to the lower inferior deep cervical nodes, and below more or less anastomosis occurs between the net-works of the thoracic and abdominal (lumbar) regions.

The Mammary Gland.—The lymphatics of the mammary gland arise in the deeper portions of the mammary tissue from sack-like enlargements situated in the connective tissue between the various lobules of the gland. The majority of the stems follow in general the course of the ducts and, passing toward the surface, communicate with an exceedingly fine subareolar net-work, which is a special development of the general subcutaneous net-work of the anterior thoracic wall. From the subareolar net-work two or more stems arise and form the principal paths for the mammary lymph, but accessory paths are also furnished by stems which arise from the sack-like enlargements and pass toward the periphery of the gland, avoiding the subareolar net-work.

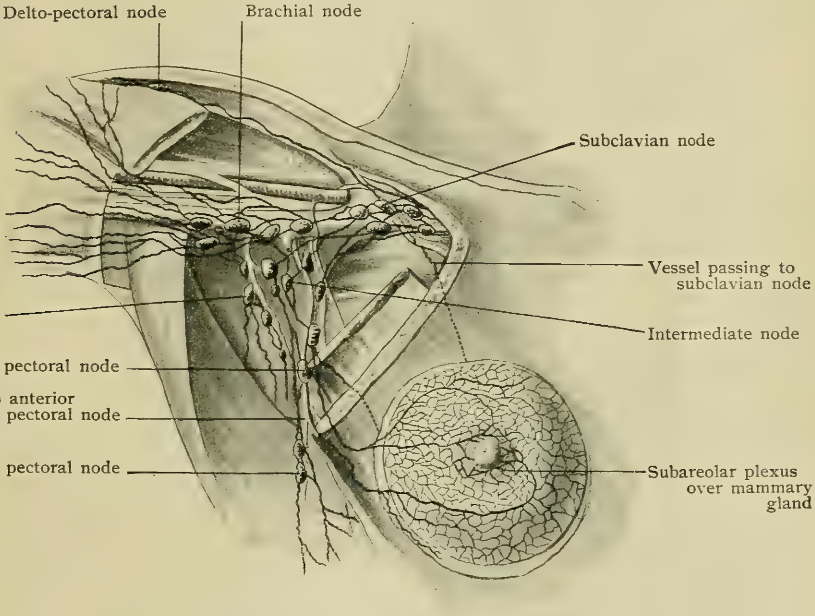
The stems which arise from the subareolar net-work pass at first almost directly outwards until they reach the lower border of the pectoralis major. They then ascend along the lower edge of this muscle for a short distance, and eventually bend

around it, perforate the axillary fascia, and terminate in the anterior pectoral nodes of the axillary plexus. Occasionally one finds along the course of one or other of the stems a small intercalated node, and one or two small nodes, the *paramammillary nodes*, may occur a short distance below the lower border of the gland on one of the efferents which passes to the lower principal stem.

The accessory paths of the mammary lymph are principally two in number. (1) In about ten per cent. of cases examined a stem issued from the deep surface of the gland, perforated the pectoralis major, and passed upward between that muscle and the pectoralis minor to terminate in the subclavicular nodes. (2) A varying number of small stems leave the medial portion of the periphery of the gland and perforate the sternal border of the pectoralis major and the intercostal muscles, to terminate in the sternal nodes.

It may be noted that the obstacle to the flow of lymph presented by enlarged axillary nodes in severe affections of the mammary gland may lead to the development of accessory or collateral paths other than those mentioned above. Thus, since the subareolar net-work is

FIG. 814.



Lymphatics of mammary gland and axillary nodes. (*Poirier and Cunéo*.*)

continuous with the general anterior thoracic subcutaneous net-work, and the latter is continuous across the median line, affection of the gland of one side may cause enlargement of the axillary nodes of the opposite side, and, furthermore, since the thoracic subcutaneous net-work is continuous with that of the abdomen, there is a possibility for the establishment of a collateral path leading to the inguinal nodes.

Furthermore, it is to be remembered that, although the anterior pectoral nodes are the termination of the principal mammary stems, yet the connection between these and other axillary nodes, especially those of the intermediate and subclavicular subgroups, is so intimate that practically all the axillary nodes may be involved, or are at least open to suspicion, in cases of mammary carcinoma.

The **intercostal lymphatics** are arranged in two sets corresponding to the two intercostal muscles (Sappey). The vessels from each internal intercostal unite to form a single stem which passes forward along the lower border of the rib forming the upper boundary of its space. The stems of the upper spaces open independently into the sternal nodes, while those from the lower spaces unite to form a common ascending stem which terminates in the lowest node of the sternal chain.

* Poirier et Charpy: Traité d'anatomie humaine, Tome ii., 1902.

The vessels from the external intercostals are somewhat larger than those from the internal muscles and have a backward direction, terminating in the intercostal nodes. It is upon these stems that the lateral intercostal nodes are situated when present. Anastomoses occur between the two sets of vessels, and the internal set also receives communicating stems from the parietal layer of the pleura, while the external one receives branches from the muscles which cover the thoracic wall, although the principal path for these leads to the axillary nodes.

The Diaphragm.—The lymphatics of the diaphragm form rich net-works upon both its surfaces, that upon the peritoneal surface being especially well developed, and numerous vessels traverse the substance of both the muscular tissue and the centrum tendineum, uniting the net-work of the abdominal with that of the thoracic surface. Upon the thoracic surface the net-work is exceedingly fine and close-meshed in the region of the centrum tendineum, being most distinct in the regions of the lateral leaflets. From this net-work branches pass outward parallel to the muscular fibres to unite with a series of anastomosing stems whose general direction is forward. Branches coming from the more peripheral portions of the diaphragm also empty into these stems, which carry the lymph forward to the diaphragmatic nodes, whence it passes to the anterior mediastinal nodes. From the net-works of the lateral leaflets of the central tendon collecting stems are also directed backward and medially towards the aortic opening, which they traverse to terminate in the upper cœliac nodes.

It is to be observed that the nodes of the thoracic surface are for the most part situated anteriorly, while the cœliac nodes, which may be regarded as the principal nodes of the inferior surface, are located posteriorly. Both sets of nodes, however, receive lymph from both surfaces of the diaphragm by means of the perforating branches which connect the upper and the lower net-works. The lower net-work is, furthermore, connected with the lymphatics of the more lateral portions of the peritoneum and also with those of the liver (page 980), while the upper net-work makes connections with the lymphatic vessels of the pleuræ. These communications, when considered in connection with the existence of the perforating branches, explain the occurrence of pleuritis as a sequence of subphrenic abscess or of the latter as a sequence of thoracic empyema.

The Heart.—The lymphatics of the heart are arranged in two principal net-works, one of which lies immediately beneath the endocardium, while the other is upon the outer surface of the organ immediately beneath the visceral layer of the pericardium. The endocardial net-work communicates with the superficial one by branches which traverse the heart musculature, and the flow of lymph from the endocardial net-work takes place only through these communicating branches. The superficial net-work extends over the whole surface of the heart, the vessels of which it is formed being well supplied with valves and arranged so as to form characteristic quadrate or rhomboidal meshes. From the net-work longitudinal stems pass upward towards the base of the heart, corresponding in a general way to the cardiac veins. Upon the anterior surface three stems are to be found passing upward along the anterior interventricular groove, parallel to the anterior cardiac vein, and, on arriving at the auriculo-ventricular groove, they unite to form a single trunk. With this another stem unites which has its origin in the net-work of the posterior surface of the heart and ascends along the posterior interventricular groove, parallel with the posterior cardiac vein. On reaching the auriculo-ventricular groove it bends round to the left and, encircling the base of the left ventricle, unites with the anterior vessels. The conjoined trunk so formed passes upward along the posterior surface of the pulmonary aorta, perforates the parietal layer of the pericardium, and terminates in one of the bronchial nodes.

From the net-work over the right side of the right ventricle another longitudinal stem arises and passes upward parallel to the right marginal vein, and, on reaching the auriculo-ventricular groove, winds around to the right and so reaches the anterior surface of the heart. It then ascends parallel with the anterior trunk, along the posterior surface of the pulmonary aorta, and also terminates in one of the bronchial nodes.

The Lungs.—The lymphatics of the lungs may be regarded as consisting of two sets, deep and superficial. The *deep set* is composed of a number of stems which accompany the branches of the pulmonary arteries and veins and of others

which are associated more especially with the bronchi. The bronchial vessels take their origin from a net-work contained in the walls of the bronchi, and are traceable along the entire length of each bronchus and its branches until the terminal bronchi are reached ; here the net-work disappears and no indications of it are to be found in the walls of the atria or alveoli. In the larger bronchi the net-work is double, one portion of it occurring immediately beneath the mucous membrane and the other external to the cartilaginous rings, but in the finer bronchi only one layer is present and from this branches pass to the stems which accompany the arteries and veins. All the stems belonging to this deep set of lymphatics pass to the hilus of the lung and there open into the pulmonary nodes.

The *superficial set* consists of a net-work situated upon the surface of the lung, immediately beneath the visceral layer of the pleura. The vessels composing it are well supplied with valves and have communicating with them branches from the visceral layer of the pleura and valved branches which have their origin in the interlobular and intralobular connective tissue. No communication has been observed between the superficial and deep pulmonary net-works, the stems from the superficial net-work alone passing directly to the hilus of the lung to terminate in the pulmonary nodes.

Lymphatic vessels have been demonstrated in the parietal layer of the pleura. Those upon its costal surface communicate with the intercostal vessels ; those upon the diaphragmatic surface with the diaphragmatic net-work ; and those upon the mediastinal surface with the posterior mediastinal nodes.

The Œsophagus.—The lymphatics of the œsophagus are arranged in two net-works, one of which is submucous, while the other is situated in the muscular coat. The stems which drain the net-works of the cervical portion of the œsophagus pass to the superior deep cervical and the recurrential nodes, while those draining the thoracic portions of the net-works pass to the posterior mediastinal nodes. Finally, the stems originating in the net-works of the terminal portion pass to the upper nodes of the cœliac group.

Practical Considerations.—*The Lymph-Nodes of the Thorax and Mediastinum. Anterior Mediastinum.* —The nodes in close relation to the internal mammary artery are of practical importance on account of their relations (*a*) to the diaphragm ; (*b*) to the anterior extremities of the intercostal spaces ; (*c*) to the inner segment of the mammary gland. They may therefore be involved in cases of subpleural (supradiaphragmatic) abscess, of tuberculous or syphilitic or typhoidal caries of the ribs or sternum, or of carcinoma of the breast (page 2035).

Middle Mediastinum.—The nodes just below the bifurcation of the trachea (bronchial, peribronchial), in close relation to the trachea, the bronchi, and the roots of the lungs, are frequently involved in tuberculous infection of the lungs. The pulmonary lymphatics, both perivascular and peribronchial, communicate on the one hand indirectly with the lymph-spaces in the walls of the alveoli beneath the epithelial cells, and on the other with these nodes. Solid particles—and this includes the bacillus tuberculosis and other organisms—are thus enabled to pass from within the alveoli into the lymphatic spaces, and from these they are forced on by the respiratory movements of the lungs to the bronchial nodes, to which all the lymphatics converge. These nodes often contain, especially in coal miners, or in the inhabitants of large cities, a large amount of black pigment, consisting of minute particles of dust, smoke (carbon), etc., that have been inhaled (Taylor).

Caseation and ulceration of these nodes have involved the trachea (page 1840), the bronchi (especially the right one, with which the larger number are in close relation), and the œsophagus (page 1614), directly in front of which some of them lie. Their enlargement has also produced various pressure symptoms,—dyspnœa, dysphagia, stridulous respiration, etc.,—which their relations easily explain.

Posterior Mediastinum.—A group of nodes—œsophago-pericardiac (Leaf)—lying between the posterior surface of the pericardium and the œsophagus, are in close relation to the trunk of the pneumogastric nerve and its œsophageal branches. Their infection—through their direct connection with the not infrequently infected nodes in the neck and thorax lying between the trachea and œsophagus—may produce symptoms of vagus irritation. It has been thought (Guiteras) that these nodes and

the bronchial nodes are especially enlarged in influenza and that some of the anomalous pulmonary symptoms of that disease—simulating congestion, pneumonia, etc., are thus accounted for. Marked enlargement of the bronchial nodes may be indicated by an area of percussion dulness below the level of the fourth dorsal vertebra (Yeo).

In cancer of the œsophagus either the mediastinal nodes or those at the root of the neck may be involved, as both sets receive lymphatics from that tube. Mediastinal growth (sarcoma) or abscess may originate in these nodes. Either condition —but especially the neoplasm—will occasion marked symptoms of pressure on the trachea, bronchi, œsophagus, and superior cava and innominate veins,—*e.g.*, dyspnœa, dysphagia, œdema of the face, neck, and upper limbs, dilatation of the superficial veins of the abdomen and thorax.

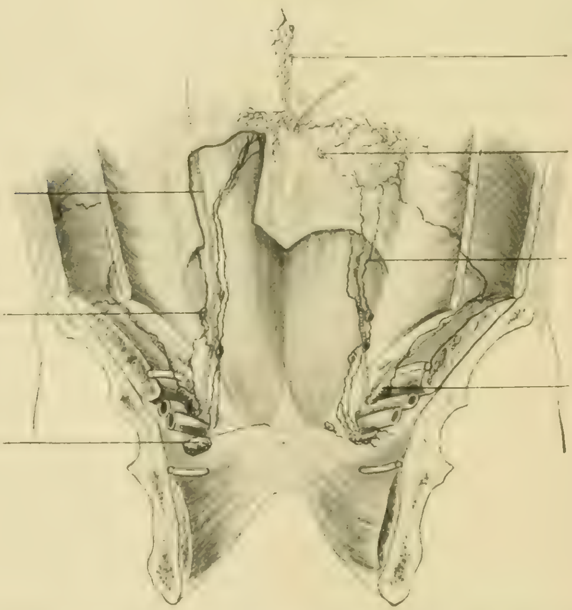
THE LYMPHATICS OF THE ABDOMEN.

The Lymph-Nodes.

The principal nodes of the abdominal region are those associated with the viscera and those situated upon the posterior wall in the vicinity of the aorta. A few small and inconstant nodes also occur upon the anterior wall, and of these the most important are the epigastric, the circumflex iliac, and the umbilical nodes.

The **epigastric nodes** (**lymphoglandulae epigastricae**) are three or four in number and are interposed in the course of the lymphatic stems which accompany

Fig. 815.



Epigastric and umbilical lymph-nodes, seen from behind. (*Cunéo and Marcille.**)

the deep epigastric vessels (Fig. 815); they occur toward the lower part of the vessels and their *efferents* pass to the lower iliac nodes.

The **circumflex iliac nodes** are from two to four in number when present, but are not unfrequently wanting. They are situated along the course of the deep circumflex iliac vessels; they receive *afferents* from the lower lateral portions of the abdominal wall, and send *efferents* to the lower iliac nodes.

The **umbilical nodes** are situated in the subserous areolar tissue in the neighborhood of the umbilicus. They are three in number, one being situated a little below and to one side of the umbilicus, and the other two above the umbilicus

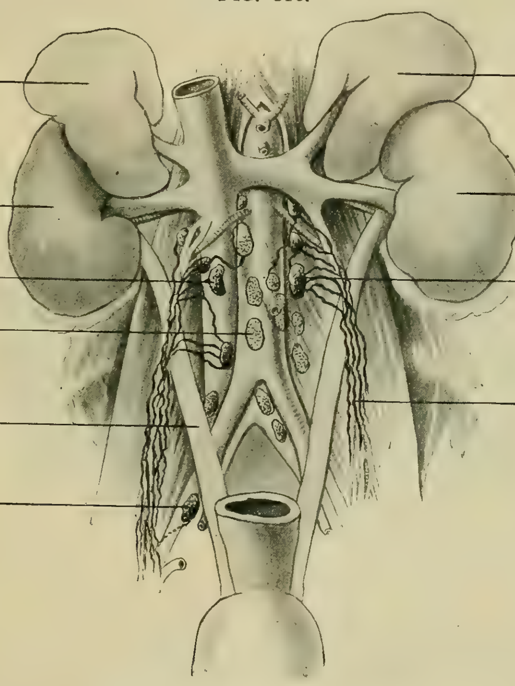
* Bull. et Mèm. Société anatom., 1901.

in the median line (Fig. 815). They occur in the net-work which covers the posterior surface of the sheath of the rectus muscles, and are apparently of inconstant occurrence.

The remaining abdominal nodes may be regarded as arranged in two principal divisions, one of which includes the groups associated with the various viscera, while the other is formed by the groups occurring in the posterior wall. This latter division may be separated into the *cœliac* and *lumbar* nodes.

The **cœliac nodes** vary in number from sixteen to twenty, and are situated in front of the abdominal aorta, around the origins of the cœliac axis and the superior mesenteric artery. They are extensively connected with one another so as to form a distinct cœliac plexus (**plexus coeliacus**). They receive *afferents* from the lower portions of the œsophagus, from the diaphragm, and from the gastric, hepatic, pancreatico-splenic, and mesenteric nodes ; the *efferents* of the lower nodes pass to the higher members of the group and the efferents of these either open independently

Fig. 816.



Lumbar nodes, new-born child. (*Cunéo.**)

into the receptaculum chyli, or, more usually, unite to form a common trunk, the truncus intestinalis, which joins the left lumbar trunk to form one of the origins of the thoracic duct (page 943).

The **lumbar nodes** (**lymphoglandulae lumbales**) are twenty to thirty in number, and form three irregular longitudinal rows along the course of the abdominal aorta (Fig. 816), extending from the level of the second lumbar vertebra to the bifurcation of the aorta, and forming with the aid of connecting vessels a well-marked plexus, the *plexus lumbalis*. The median row is composed of some five or six large nodes situated upon the anterior surface of the aorta, and of four or five retro-aortic nodes which rest upon the bodies of the third and fourth lumbar vertebræ, immediately below the lower extremity of the receptaculum chyli. Of the lateral rows that of the left side is formed by a number of nodes arranged in an almost vertical series upon the successive heads of the psoas muscle. The right lateral nodes occupy a

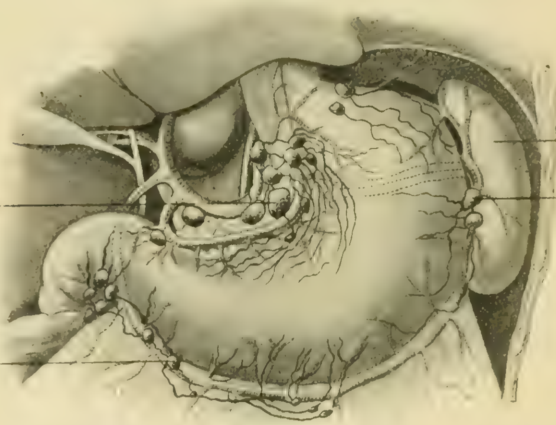
* Bull. et Mèm. Société anatom., 1901.

corresponding position with relation to the right psoas, lying posterior to the vena cava inferior, but a varying number of nodes which may be referred to this group also occur upon the anterior surface of that vessel.

Since all the nodes are united by communicating vessels, they form a plexus and will receive afferents from and give efferents to one another. In addition, the median row receives *afferents* from the descending colon and the mesocolic nodes, while the lateral rows receive them from the muscles of the posterior abdominal walls, from the iliac nodes, from the testes in the male and the ovaries, Fallopian tubes, and uterus in the female, and from the kidneys and suprarenal capsules. The *efferents* of the upper nodes of the median row pass upward to terminate in the lower cœliac nodes, while those of the lateral rows either pass to the nodes of the median row, or unite together to form on either side a common trunk, the **truncus lumbalis,** which unites with its fellow to form the receptaculum chyli (page 943), or else they perforate the crus of the diaphragm and open independently into the thoracic duct.

The **visceral abdominal nodes** are arranged in groups or chains which follow in general the principal visceral branches of the aorta, those following the branches of the cœliac axis and the superior mesenteric artery communicating by their efferents

FIG. 817.



Lymphatic nodes and vessels of stomach. (*Polya and Navratil.**)

mainly with the cœliac nodes, while those accompanying the inferior mesenteric branches communicate with the median lumbar nodes.

Corresponding with the branches of the cœliac axis are the gastric, hepatic, and pancreatico-splenic nodes. The **gastric nodes** consist of two chains (**lymphoglandulae gastricae superiores et inferiores**) situated respectively along the lesser and greater curvatures of the stomach. The superior nodes, three to fifteen in number, are situated along the course of the gastric artery, principally along the lesser curvature of the stomach between the two layers of the gastro-hepatic omentum (Fig. 817), although a few also occur along the course of the artery before it reaches the stomach and others upon the left side of the cardiac orifice of the viscus. The inferior nodes are situated in the vicinity of the pyloric end of the stomach, partly along the right half of the greater curvature, accompanying the right gastro-epiploic vessels, and partly on the posterior surface of the pylorus along the course of the gastro-duodenal vessels. The gastric nodes receive *afferents* from the stomach and in the case of the retro-pyloric nodes also from the first portion of the duodenum, and their *efferents* pass to the cœliac nodes, those of the superior group following the course of the gastric vessels, while those from the inferior group accompany the gastro-duodenal and hepatic arteries.

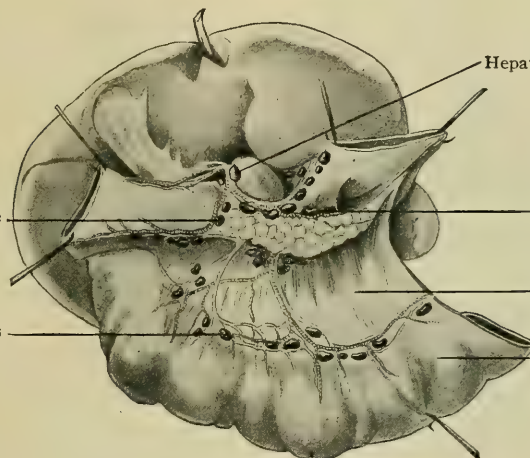
* Deutsche Zeitschrift f. Chirurgie, Bd. lxix.

The **hepatic nodes** (lymphoglandulae hepaticae) are more or less clearly arranged in two series. One series accompanies the main stem of the hepatic artery along the upper border of the head of the pancreas and throughout the vertical portion of its course in the free margin of the gastro-hepatic omentum, and the other accompanies the superior pancreatico-duodenal branch and ascends along the bile-duct to the portal fissure. The *afferents* of the nodes come from the liver, the head of the pancreas, and the first and second portions of the duodenum, and their *efferents* pass to the cœliac nodes.

The **pancreatico-splenic nodes** (lymphoglandulae pancreaticolienales) accompany the splenic artery throughout the greater portion of its course, and are consequently situated along and partly behind the upper border of the pancreas (Fig. 818). They vary in number from four to ten, and their *afferents* come from the organs supplied by the splenic artery,—namely, the stomach, pancreas, and spleen,—while their *efferents* pass to the cœliac nodes.

The **mesenteric nodes** (lymphoglandulae mesentericae) are from one hundred to two hundred in number, and are arranged along the superior mesenteric artery and its branches to the small intestine. They form three more or less distinct series, especially towards the upper portion of the mesentery. One series, in which the

FIG. 818.



Pancreatico-splenic, retropyloric, and mesocolic nodes, new-born child; liver drawn upward, stomach and duodenum laterally. (*Cunéo and Delamare.**)

nodes are more numerous and smaller than the others, lies close to the intestine, among the terminal branches of the artery; a second consists of larger scattered nodes situated along the primary branches of the artery; while the third series includes the closely aggregated nodes which surround its main stem. Towards the lower portion of the ileum the distinction of the first and second series becomes less and less apparent, and at the junction of the ileum and cæcum the nodes form a single group, situated a short distance from the intestine between the two layers of the mesentery. These nodes are sometimes termed the **ileo-cæcal nodes,** and associated with them by means of its efferents is a variable group of small nodes, the **appendicular nodes,** situated partly in the base of the mesenteriole of the appendix and partly in the immediate vicinity of the junction of the ileum and cæcum (Fig. 820).

The various series of nodes are connected with one another by vessels, which in this region are known as **lacteals,** and the nodes of the first series receive their *afferents* from the walls of the small intestine, and, in the case of the ileo-cæcal nodes, from the cæcum and vermiform appendix. The *efferents* of the nodes of the third series pass to those nodes of the cœliac group which are situated around the origin of the superior mesenteric artery.

* Jour. de l'anat. et de la physiol., Tome xxxvi., 1900.

The nodes which are associated with the abdominal portions of the large intestine are known as the **mesocolic nodes** (**lymphoglandulae mesocolicae**) and they consist of from twenty to fifty small nodes which are situated close to the intestine (Fig. 818). Their *afferents* are received from the entire length of the large intestine, with the exception of the cæcum and appendix and the rectum, and the *efferents* of the nodes associated with the ascending colon and the right half of the transverse colon pass to the lower cœliac nodes, while those of the nodes associated with the left half of the transverse colon and with the descending and sigmoid colons pass to the median row of lumbar nodes.

In addition to the nodes which are properly included in the mesocolic group there are a number of small nodes situated upon the lateral walls of the upper part of the rectum, along the lines of the superior hemorrhoidal vessels (Fig. 821). These **ano-rectal nodes** are from two to eight in number on each side, and are situated beneath the fibrous investment of the rectum, resting directly upon the outer surface of the muscular coat. They receive their *afferents* from the neighboring portions of the wall of the rectum and, in the female, from the posterior surface of the vagina, and their *efferents* pass to the mesocolic nodes situated in the lower part of the mesentery of the sigmoid colon.

The Lymphatic Vessels.

The Abdominal Walls.—The anterior abdominal wall, as regards its lymphatic vessels, may be divided into a supra- and an infra-umbilical region. The lymphatics of the former area belong in reality to the thoracic cutaneous set, passing upward to join the thoracic stems which terminate in the anterior pectoral nodes of the axillary plexus. The vessels of the infra-umbilical region, on the contrary, descend to terminate in the inguinal nodes. Along the line of junction of the two regions anastomoses occur and the vessels of the right half of the abdominal wall also communicate with those of the left half. The subcutaneous vessels of the posterior abdominal and lumbar regions anastomose with the corresponding vessels of the posterior thoracic region above, and below with those of the gluteal region. They form an extensive net-work, from which stems pass downward and forward, parallel with the crest of the ilium, to terminate in the inguinal nodes.

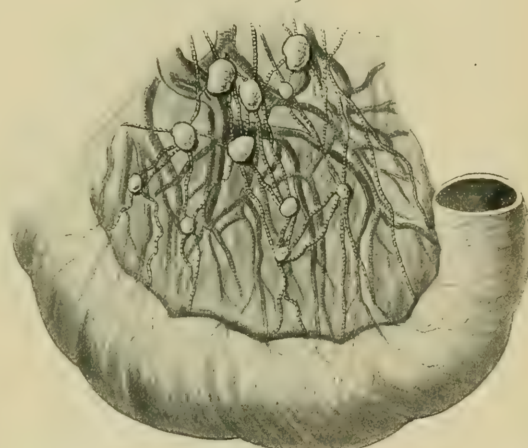
The lymphatic net-work of the deeper structures of the abdominal walls is drained by a number of stems which follow in general the courses of the blood-vessels. Thus, the stems which lead away from the upper portion of the abdominal wall pass upward along the course of the superior epigastric vessels to terminate in the lower sternal nodes; another set follows the course of the deep epigastric vessels to terminate in the lower iliac nodes, after traversing the epigastric nodes; another accompanies the deep circumflex iliac vessels, draining the lower portions of the lateral walls of the abdomen, traversing the circumflex iliac nodes, and also terminating in the iliac nodes; while other sets accompany the lumbar vessels and terminate in the lateral rows of lumbar nodes. Abundant communications exist between the vessels of adjacent drainage areas and from the region of the umbilicus the lymph flow may follow any one of the paths mentioned above. Attention may be called to the occasional presence of nodes in the course of the vessels arising in the umbilical region (page 972).

The Stomach.—The lymphatics of the stomach have their origin in two net-works, one of which is situated in the mucosa and the other in the muscular coat. The net-work of the mucosa occurs uninterruptedly throughout the entire extent of the gastric surface and is continuous with the corresponding net-works of both the œsophagus and duodenum. From its deeper surface branches pass to a more open net-work situated upon the outer surface of the submucosa, and from this stems traverse the muscular coat obliquely to terminate in a subserous net-work which also receives branches from the net-work of the muscular coat. Connections between the muscular and mucous net-works occur, but they are so indirect that an extensive cancerous infection of the mucosa may reach the outer layers of the stomach only at limited areas at some distance from one another.

The subserous net-work with which both primary net-works communicate gives origin to a number of stems which pass to the gastric nodes, and the course which they follow is such that the entire surface of the stomach may be regarded as presenting

three more or less distinct lymphatic areas (Fig. 817). Not that the areas are perfectly separated from one another; on the contrary, the subserous net-work is continuous over the entire surface. But the collecting stems from each area follow a definite route toward different node groups. The largest of these areas occupies roughly the whole of the upper border of the stomach from the fundus to the pylorus, and extends downward on either surface to about two-thirds of the distance to the greater curvature. Its collecting stems all pass to the superior cardiac nodes. The second area occupies about the pyloric two-thirds of the greater curvature, and its efferents pass to the inferior gastric nodes, while the third and smallest area occupies the lower part of the fundus and the cardiac one-third of the greater curvature, and sends its efferents to the splenic nodes. It may be remarked that these areas correspond in a general way with the areas drained by the principal veins arising in the stomach walls. Thus, the large upper area corresponds in general with the drainage area of the gastric vein, the lower pyloric area to that of the right gastro-epiploic vein, and the lower cardiac area to that of the left gastro-epiploic. It may further be noted that while the subserous net-work communicates with the superficial net-work of the œsophagus, it seems to be completely cut off from connection with the corresponding duodenal net-work, an arrangement which is in striking contrast to the continuity which exists between the gastric and duodenal mucosa net-works and explains the rare extension of a carcinomatous infection of the pylorus to the duodenum by the subserous route.

FIG. 819.



Mesenteric lymphatic nodes and vessels; peritoneal covering of mesentery has been removed.

The Small Intestine.—Throughout the entire length of the intestine, both small and large, the lymphatic net-works are arranged in two sets, one of which is situated in the mucosa and the other in the muscular coat. The two net-works are more or less independent, though communicating branches occur, and both open into a subserous net-work from which collecting stems arise.

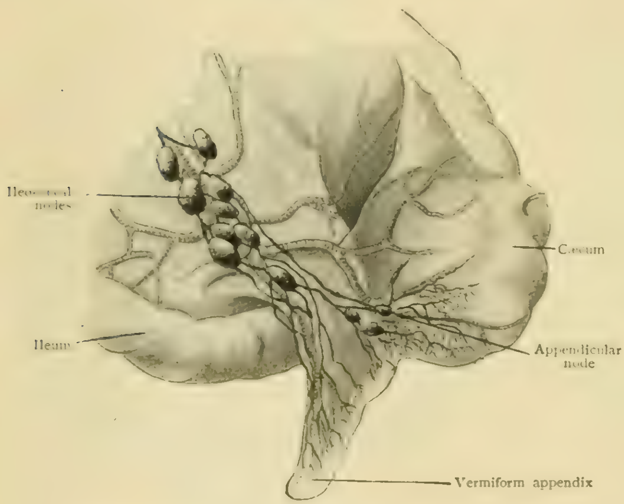
The stems which pass from the duodenum are divisible into two groups according as they arise from the anterior or posterior surface. Those coming from the anterior surface pass to the chain of nodes situated along the course of the inferior pancreatico-duodenal artery, and so to the cœliac nodes, which surround the origin of the superior mesenteric artery, while the posterior stems pass to the hepatic nodes situated along the course of the superior pancreatico-duodenal vessels and so to the cœliac nodes which surround the cœliac axis. Some of the stems which take their origin from the first part of the duodenum pass to those nodes of the inferior gastric group which are situated upon the posterior surface of the pyloric region of the stomach, and, since these nodes also receive afferents from the pylorus, they afford opportunity for the transference of a superficial infection from the pylorus to the duodenum, a direct route for infection in this direction being wanting (see above).

The collecting stems of the jejunum and ileum pass to the first series of mesenteric nodes, situated along the line of attachment of the mesentery to the intestine, and, after traversing these, are continued onward to the second and third series of nodes, whose efferents pass to the cœliac nodes surrounding the origin of the superior mesenteric artery. The vessels issuing from the jejuno-ileum are usually spoken of as the **lacteals**, on account of their contents, especially at times when absorption of food constituents is proceeding rapidly in the intestine, having a milky appearance, owing to the presence of numerous fat globules in the lymphocytes.

The Large Intestine.—The two sets of lymphatic net-works characteristic of mucous membranes occur in the walls of the large intestine, and they communicate with one another and finally open into a subserous net-work from which collecting stems take origin. In the vermiform appendix (Fig. 820) these collecting stems are from three to five in number and pass upward in the mesenteriole to terminate in the appendicular nodes or, in the absence of these, directly in the ileo-cæcal nodes. The subserous net-work of the base of the appendix communicates freely with that of the cæcum, whose collecting stems have essentially the same course as those of the appendix, passing primarily to the appendicular nodes situated in the neighborhood of the ileo-cæcal junction and thence to the ileo-cæcal nodes. The ultimate nodes of the appendicular and cæcal systems are situated in the root of the mesentery along the course of the superior mesenteric vessels ; they belong to the group of mesenteric nodes and receive their afferents in part from the ileo-cæcal nodes.

Communications have been described as existing between the appendicular lymphatics and those of the broad ligament of the uterus as well as the iliac nodes. The more recent observations have failed, however, to confirm the existence of any direct connection with these structures, and pathological conditions of the broad ligament and iliac nodes associated with acute appendicitis may perhaps be due to a dissemination of the infection through the subperitoneal net-work by way of the so-called appendiculo-ovarian ligament.

FIG. 820.



Ileo-cæcal and appendicular lymphatic nodes and vessels. (*Polya and Navratil.**)

The collecting stems from the subserous net-work of the *ascending colon* pass primarily to some inconstant mesocolic nodes, situated along the line of attachment of the colon to the abdominal wall, and thence are continued along the lines followed by the right colic vessels to the superior mesenteric nodes. The stems from the *transverse colon* have a more varied course in accordance with the arrangement of the blood-vessels. They pass primarily to a series of mesocolic nodes situated between the layers of the transverse mesocolon close to the intestine ; these are of larger size and more numerous than the nodes associated with either the ascending or descending colon and are especially well developed toward either angle of the colon. Their efferents pass principally to some four or five nodes situated along the course of the middle colic vessels and thence to the third group of mesenteric nodes, but those from the vicinity of the splenic flexure follow the course of the branches of the left colic vessels and so pass to the nodes of the median lumbar group situated in the neighborhood of the inferior mesenteric artery. The lymphatics of the transverse colon communicate somewhat extensively with those of the great omentum, as the result of the attachment of the latter to the colon, and they are thus placed in connection with the inferior gastric and splenic nodes.

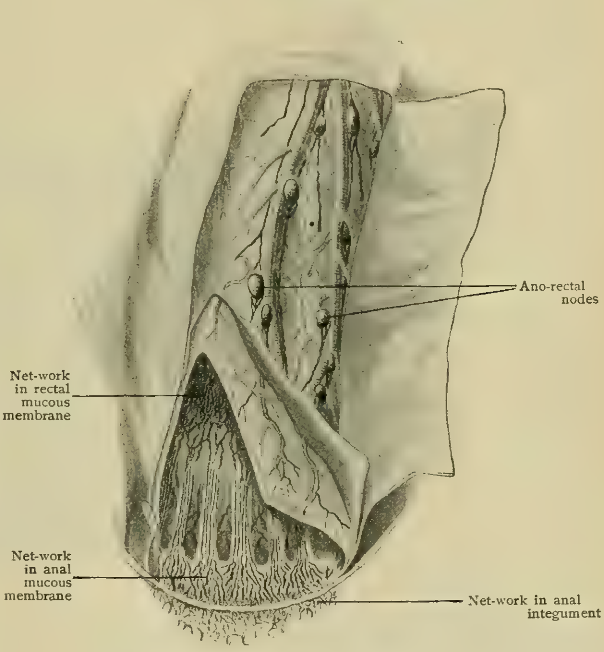
The collecting stems from the *descending colon* and sigmoid flexure pass primarily to mesocolic nodes situated close to the attached surface of the intestine, and thence follow the courses of the left colic and sigmoid vessels to the median lumbar nodes situated in the vicinity of the origin of the inferior mesenteric artery.

* Deutsche Zeitschrift f. Chirurgie, Bd. lxix.

The mesocolic nodes associated with the descending colon are less numerous and smaller than those of the sigmoid flexure and resemble in appearance and arrangement those of the ascending colon.

The lymphatics of the *rectum* (Fig. 821), although belonging in large part to the pelvic region, may, for the sake of completeness of the account of the intestinal lymphatics, be considered here in their entirety. Of the two primary net-works that of the muscular coat is injected only with difficulty, but it communicates with the mucosa net-work and its collecting stems follow the same course as those of the deeper net-work. In the mucosa net-work two zones may be distinguished, one of which includes the greater portion of the net-work and extends down to the lower ends of the columns of Morgagni, while the other includes that portion of the mucosa intervening between that level and the anal integument. The upper zone may be termed the net-work of the rectal mucosa, while the lower one may be designated as the net-work of the anal mucosa, since the region in which it occurs forms the transition between the mucosa and the anal integument.

FIG. 821.



Lymphatics of rectum. (*Gerota*.*)

The collecting stems from the net-work of the rectal mucosa traverse the muscular coat and enter into relation with the ano-rectal nodes (page 976). After traversing these they are continued onward along the course of the superior hemorrhoidal vessels and open into the lower mesocolic nodes, from which efferents pass to the median lumbar nodes situated in the neighborhood of the origin of the inferior mesenteric artery. The net-work of the anal mucosa sends numerous branches upward to communicate with the lower part of the rectal mucosa net-work. These branches traverse for the most part the columns of Morgagni in which they are so numerous as to earn for themselves the appellation of *glomi lymphatici*, while, on the other hand, the mucosa of the depressions between the columns is comparatively poor in lymphatics. Some collecting stems from the anal mucosa perforate the muscular coat and pass to the ano-rectal nodes, and thence along with the stems from the rectal mucosa to the lower mesocolic nodes, while others follow the course of the middle hemorrhoidal vessels and terminate in nodes belonging to the hypogastric group (page 984) situated at the point where the internal iliac artery divides into its leash of branches, or else at the level of the great sacro-sciatic notch, a little below the point where the obturator vein joins the internal iliac.

The lymphatics of the *anal integument* will be considered together with those of the perineal region (page 987).

The Pancreas.—The lymphatics of the pancreas take their origin from a perilobular net-work from which collecting stems pass to the neighboring nodes, following the course of the blood-vessels which supply the gland. The great majority of them pass to the chain of splenic nodes which extends along the upper border of the pancreas, but those of the head of the gland pass in part to nodes of the hepatic

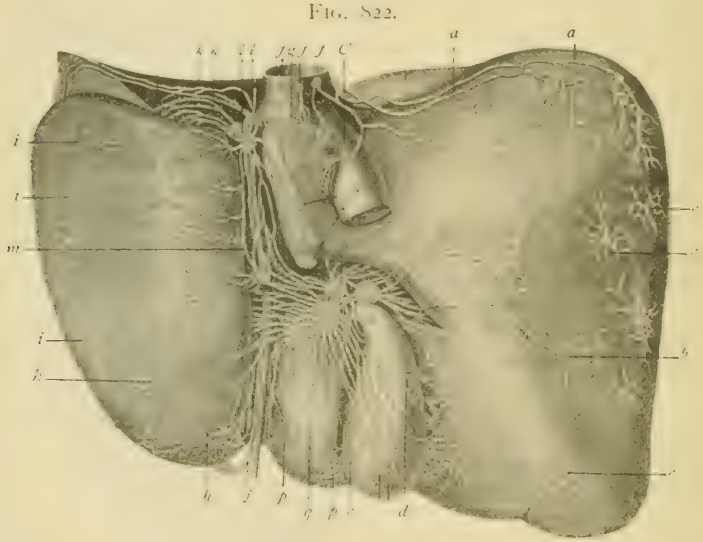
* Archiv f. Anat. u. Physiol., 1895.

group, following the course of the superior pancreatico-duodenal vessels, while others again accompany the inferior pancreatico-duodenal vessels to terminate in nodes belonging to the mesenteric group.

The Liver.—The lymphatics of the liver are arranged in perilobular net-works from which stems pass in two principal directions; those which come from the deeper portions of the net-work follow the course of either the portal or hepatic venous branches, while those arising from the net-works surrounding the more superficial lobules pass to the surface of the liver, upon which they anastomose extensively to form a subserous net-work from which efferent stems arise.

The *deep* efferents which accompany the branches of the portal vein take their course in the substance of the capsule of Glisson, two or three stems accompanying each of the larger branches of the vein and anastomosing with one another to form a plexus around the vessel and the accompanying branches of the hepatic artery and bile-duct. As the branches of the vein are followed to their union to form larger trunks, the accompanying lymphatics unite to a considerable extent, so that from fifteen to twenty stems emerge at the transverse fissure and terminate in the hepatic

FIG. 822.



Lymphatics of postero-inferior surface of liver. *a, a,* trunks arising from vicinity of right border of liver and going to one of the nodes surrounding inferior cava (*C*) as it enters thorax; *b,* trunk arising from inferior surface of right lobe and emptying at hilum into nodes resting on neck of gall-bladder; *c,* trunks arising near gall-bladder and going to lower hilum-nodes; *d,* trunks running on attached surface of gall-bladder; *e, e, e,* trunks that take origin from superficial net-works and disappear in liver to follow branches of portal vein to hilum-nodes; *f, f, f,* caval nodes receiving vessels from Spigelian lobe (*g*); *h, h,* principal trunks of left lobe; *i, i, i,* trunks that arise from superficial net-works and dip into liver to join vessels in capsule of Glisson; *j,* trunks from superior surface of liver which follow round ligament to hilum-nodes; *k,* trunks from superior surface that end in nodes in posterior part of longitudinal fissure (*l*); *m,* trunks connecting these nodes with those in hilum; *n* (14), nodes connected with terminal part of œsophagus; *o, o, o* (15), hilum nodes which receive all trunks accompanying vena porta and large part of those from inferior surface; *p, p,* vessels from quadrate lobe (*q*). (*Sappey.**)

nodes situated in the fissure. The stems which accompany the branches of the hepatic vein also form more or less distinct plexuses, and, when they emerge from the liver substance, are from five to six in number. They continue upward along the inferior vena cava, pass with it through the diaphragm, and terminate in the nodes situated on the convex surface of the diaphragm around the orifice for the vena cava.

The *superficial* vessels have more diversified courses, and it will be convenient to consider them as belonging to two groups according as they arise from the superior or inferior surface of the liver. And first those arising from the net-work of the superior surface may be described. Those which arise toward the posterior portion of the surface of both the right and left lobes pass mainly toward the vena cava inferior and ascend with it through the diaphragm to terminate in the nodes situated

* Description et Iconographie des Vaisseaux lymphatiques, 1874.

around the opening for the vena cava. From the more lateral portions of each lobe, however, the collecting stems take a different course, those from the right lobe uniting to form a single stem which passes backward between the layers of the right lateral (triangular) ligament, and then passes medially over the surface of the right crus of the diaphragm to terminate in the nodes surrounding the cœliac axis. Those from the lateral portions of the left lobe pass backward between the layers of the left lateral (triangular) ligament and terminate in the nodes of the superior gastric group which are situated in the neighborhood of the cardiac orifice of the stomach.

The collecting stems of the anterior portion of the *superior surface* are relatively small and are more conspicuous on the right lobe than on the left. They pass forward and downward to curve around the anterior border of the liver, and join with the stems arising from the quadrate lobe and gall-bladder to pass with these to the hepatic nodes situated in the transverse fissure. Finally, much more important than these, is a group of vessels which arise from a rich subserous net-work situated along the line of attachment of the suspensory (falciform) ligament. Some of these vessels take a backward course toward the vena cava and accompany the other vessels of the superior surface which terminate in the caval diaphragmatic nodes, and others pass forward until they meet the upper portion of the round ligament, which they follow to reach the nodes situated in the transverse fissure. The remaining stems of the group, from three to ten in number, pass forward and upward, between the layers of the suspensory ligament, toward the under surface of the diaphragm, traverse that structure near its anterior attachment, and come into connection with a number of small nodes situated behind the xiphoid process of the sternum. From these they are continued upward along the course of the internal mammary vessels to terminate in the lower nodes of the inferior deep cervical group, usually upon the left side, rarely upon the right. This path is of importance as furnishing a direct route by which the metastasis of the left supraclavicular nodes, frequently induced by abdominal carcinomata, may be produced. It must, furthermore, be noted that both these vessels and others which arise from the superior surface of the liver communicate somewhat extensively with the net-work occurring on the under surface of the diaphragm, and since this net-work communicates abundantly with that of the thoracic surface of the diaphragm, and this again with the vessels of the pleuræ, opportunity is afforded for the development of pleuritis, especially upon the right side, as a result of a subdiaphragmatic infection.

Turning now to the stems arising from the superficial net-work of the *inferior surface* of the liver, it will be found that they pass principally to the hepatic nodes situated in the transverse fissure, at least these nodes form the termination for the vessels passing from the left and quadrate lobes, the left half of the Spigelian and the anterior and middle portions of the right lobe. Those, however, which take their origin toward the posterior part of the right lobe and from the right half of the Spigelian pass to the vena cava and, ascending along it, terminate in the diaphragmatic nodes surrounding its opening into the thorax.

The lymphatics of the **gall-bladder** and **common bile-duct** have their origin in two net-works, one of which is situated in the mucosa and the other in the muscular coat. Efferents from both net-works pass to the surface to form a superficial net-work, from which collecting stems pass, in the case of the gall-bladder to the nodes situated in the transverse fissure, and in the case of the duct for the most part to a chain of nodes belonging to the hepatic group, which occurs along the line of the duct in the edge of the gastro-hepatic omentum ; those from the lower portion of the duct, however, associate themselves with stems from the duodenum and head of the pancreas which open into the uppermost nodes situated along the course of the superior pancreatico-duodenal vessels.

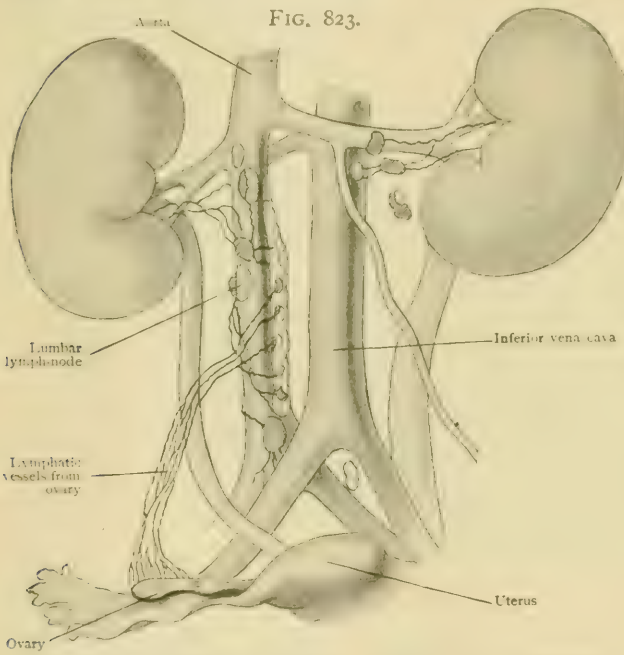
Stated in brief, the destinations of the hepatic lymphatics are principally the hepatic nodes situated in the transverse fissure and the diaphragmatic nodes which surround the opening of the inferior vena cava. A vessel from the right lobe also passes to the cœliac nodes, some from the left lobe to the superior gastric nodes, and an important group passes up in the suspensory ligament to communicate with some of the anterior diaphragmatic nodes and terminate in the lower inferior deep

cervical nodes. Finally, it is to be remembered that numerous communications exist between the superficial hepatic lymphatics and those which form the net-work on the abdominal surface of the diaphragm.

The Spleen.—The lymphatics of the spleen are arranged in a superficial and a deep set, numerous communications occurring between the two. The vessels of the superficial set are subserous in position and converge toward the hilus to terminate in the adjacent pancreatico-splenic nodes, to which the deep lymphatics, which accompany the blood-vessels of the spleen, also pass.

The Kidneys and Ureters.—The lymphatics of the kidney form three net-works, one of which is situated in the cortical tissue of the kidney, the second, whose meshes are very fine, is situated immediately beneath the fibrous capsule, while the third occurs beneath the peritoneum in the superficial portions of the adipose capsule. The efferents of the cortical net-work follow the branches of the renal vessels through the medullary substance and emerge at the hilus in the form of from four to seven vessels, which pass toward the median line of the posterior abdominal wall along the course of the renal veins, and terminate in the upper nodes of the lateral lumbar groups (Fig. 823). Those which come from the right kidney terminate partly in nodes which lie in front of the inferior vena cava, and partly in two or three large nodes which are situated behind that vessel upon the right crus of the diaphragm. The efferents from these nodes pierce the crus and terminate directly in the thoracic duct. The uppermost nodes to which the vessels of the left kidney pass are situated upon the left crus of the diaphragm and their efferents also pierce the crus to open into the thoracic duct; the efferents from the remaining nodes concerned unite with those of the other lateral lumbar nodes to form the lumbar trunks which open into the receptaculum chyli.

FIG. 823.



Lymphatics of kidneys and of ovary, new-born child. (*Stahr.**)

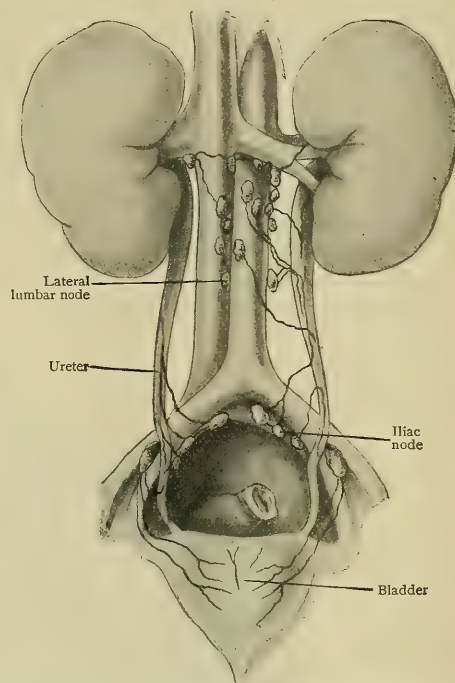
The net-work which lies beneath the fibrous capsule communicates with both the cortical and subserous net-works, and its drainage is probably mainly through these: a few stems, however, pass toward the hilus, beneath the capsule, and unite with the terminal efferents from the cortical net-work, there being no direct connection between the net-work and the lumbar nodes. The case is different with the subserous net-work, its efferents passing to the upper lateral lumbar nodes quite independently of the cortical efferents. As already noted, it has abundant communication with the net-work beneath the fibrous capsule, and through this with the cortical net-work, so that infections of the kidney tissue are readily communicated to the adipose capsule.

The lymphatic net-works of the **ureters** appear to be limited to the muscular coat and the surface of the ducts (Sakata). The efferents which arise from the upper portions of the net-works, that is to say from the portions above the level at

* Archiv f. Anat. u. Physiol., 1900.

which the ureter is crossed by the spermatic (ovarian) artery, pass upward to unite with the renal efferents or occasionally to terminate directly in the upper lateral lumbar nodes (Fig. 824). The majority of the efferents arise from those portions of the ducts intervening between the crossing of the spermatic (ovarian) arteries and the level at which the ureters cross the common iliac vessels to enter the pelvis, and these vessels pass either to the lower lateral lumbar nodes, or else, in the case of the lower ones, to the upper iliac nodes. Finally, the efferents from the pelvic portions of the ureters either unite with the vessels passing from the bladder, or else communicate directly with certain of the hypogastric nodes.

Fig. 824.



Lymphatics of ureters. (Based on several figures by *Sakata*.*)

In and beneath the fibrous capsule of the **suprarenal bodies** a lymphatic net-work occurs, whose efferents on the one hand join the renal lymphatics, and on the other pass into the substance of the organs to communicate with a net-work situated in the glomerular portion of the cortex. From this latter net-work stems pass centrally in the partitions between the cell columns of the cortex to unite with a rich plexus which traverses all portions of the medullary substance. The main stems of this plexus follow the course of the suprarenal blood-vessels and emerge at the hilus of the organ as four or five stems, which pass to the upper lateral lumbar nodes. Some of the stems are also said to pierce the crura of the diaphragm and terminate in the lower nodes of the posterior mediastinal group.

THE LYMPHATICS OF THE PELVIS.

The Lymph-Nodes.

The pelvic lymphatic nodes are arranged along the courses of the principal vessels, and may conveniently be divided into three groups, the iliac, the hypogastric, and the sacral nodes. In addition some small inconstant nodes occur in association with the bladder and these will be described in connection with the vessels arising from that organ (page 985). The epigastric and circumflex iliac nodes, already described in connection with the abdominal region (page 972), are really outliers of the iliac group.

The **iliac nodes** (Fig. 825) are from fifteen to twenty in number and form a plexus (**plexus iliacus externus**) along the course of the common and external iliac vessels, the uppermost nodes lying at the level of the bifurcation of the aorta and the lowermost around the point of exit of the external iliac vessels beneath Poupart's ligament. Three more or less distinct linear series of nodes can be recognized in the plexus, one of which, along the course of the common iliac artery, is situated close to the outer surface of the artery and along the medial border of the psoas muscle. The second lies behind the artery, resting upon the anterior surface of the vein, while the third unites with its fellow of the opposite side to form a group of three or four nodes resting upon the left common iliac vein and the promontory of the sacrum in the angle formed by the bifurcation of the aorta. Of the series along the line of the external iliac vessels one lies to the outer side of the artery along the medial

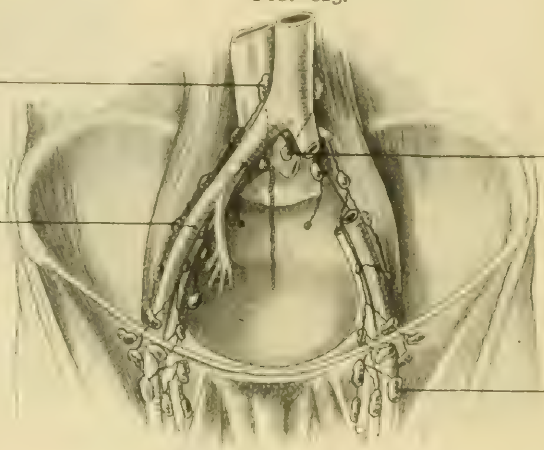
* Archiv f. Anatom. u. Physiol., 1903.

border of the psoas, the second in the angle between the vein and the artery, and the third along the lower border of the vein, between it and the obturator nerve.

The various nodes of the iliac set communicate with one another so that the *efferents* of one node are *afferents* for the higher ones. In addition they receive *afferents* from the inguinal nodes as well as from the epigastric and circumflex iliac nodes as already stated, and the group situated over the promontory of the sacrum also receives afferents from both the hypogastric and sacral nodes. Furthermore, afferents pass to the iliac nodes from the pelvic portions of the ureters, from the bladder and prostate gland, from the lower portion of the uterus and the upper portion of the vagina, from the glans penis and clitoris, from the adductor muscles of the thigh through vessels accompanying the obturator artery, and, in the case of the lateral series of nodes, from the psoas muscle and the adjacent subserous tissue. The *efferents* pass to the lower lateral lumbar nodes.

The **internal iliac or hypogastric nodes** (**lymphoglandulae hypogastricae**) are from nine to twelve in number on each side, and are situated on the lateral walls of the pelvic cavity, along the course of the internal iliac vessel and its branches

Fig. 825.



Iliac nodes. (*Cunéo and Marcille.**)

(Fig. 825). They are connected together to form a plexus (**plexus hypogastricus**), and receive *afferents* from most of the regions to which the branches of the internal iliac artery are distributed. Thus branches come to them from all the pelvic organs, from the deeper portions of the perineum, including the penial portion of the urethra, from the deep portions of the posterior and internal femoral and the gluteal regions. Their *efferents* pass mainly to the iliac nodes situated on the promontory of the sacrum, those which arise from the obturator node, situated upon the obturator artery as it passes through the obturator foramen, passing, however, to nodes belonging to the inner series of the group accompanying the external iliac vessels.

The **sacral nodes** are situated on the ventral surface of the sacrum, partly along the course of the middle sacral vessels, and partly internal to the second and third anterior sacral foramina, along the course of the lateral sacral arteries (Fig. 829). All the nodes are small and they are united together by lymphatic vessels to form a sacral plexus (**plexus sacralis medius**). They receive *afferents* from the neighboring muscles and from the sacrum, and their *efferents* pass to the iliac nodes situated upon the promontory of the sacrum.

The Lymphatic Vessels.

Under this heading will be considered the vessels of the various pelvic organs, with the exception of those of the rectum, which have already been described (page 979). In addition there will be included the vessels of the external genitalia,

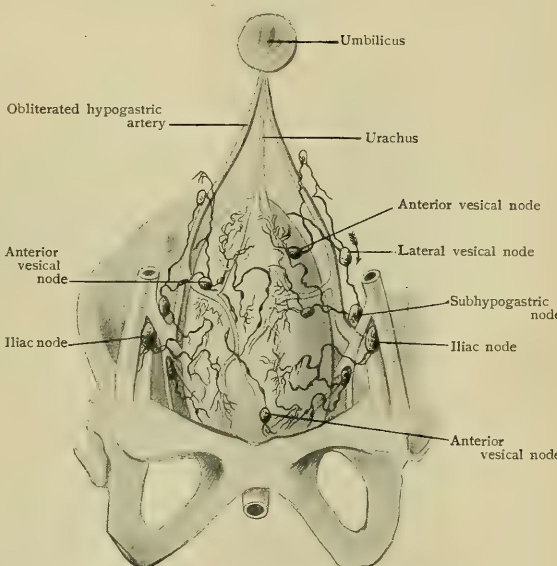
* Bull. et Mèm. Société anatom., 1901.

and, on account of their intimate relation with these, the superficial lymphatics of the perineal and circumanal regions.

The Bladder.—It was for a long time a matter for discussion whether or not the mucosa of the bladder was provided with a lymphatic net-work, but the general consensus of recent observers is that it is not. Only the muscular coat possesses a net-work, and from this stems pass to the surface of the viscus to form a superficial net-work beneath the peritoneal or fascial investment. This net-work is continuous at the neck of the bladder with those of the urethra and prostate gland, and, at its base, with the net-works of the ureters and seminal vesicles, and, in the female, of the vagina. The efferent stems which take origin from it may be divided into two groups according as they arise upon the anterior or posterior surface.

Those passing from the lower part of the anterior surface are directed laterally and those from the upper part pursue a flexuous course downward and laterally to terminate in the nodes of the iliac group situated along the external iliac vessels (Fig. 826). In their course they usually traverse some small nodes situated in close proximity to the bladder and divisible according to their position into two groups. One of these is situated upon the anterior surface of the bladder, and consists of two or three nodes, the **anterior vesical nodes,** two of which are usually situated near the apex of the viscus in the course of the superior vesical artery, while the third occurs lower down in the retropubic tissue. The other group consists of from two to four nodes, the **lateral vesical nodes,** situated on either side of the bladder along the course of the obliterated hypogastric arteries. Both groups are somewhat inconstant, but occur in a large percentage of cases.

Fig. 826.



Lymph-nodes of bladder. (Based on figures of *Gerota.**)

The vessels from the upper part of the *posterior surface* of the bladder pass downward and laterally, often traversing some of the lateral vesical nodes, and terminate in the external iliac nodes which receive the stems from the anterior surface. Others pass to the hypogastric nodes, while others again, arising from the base of the bladder, pass at first directly backward past the lateral surfaces of the rectum and then ascend on the sacrum to terminate in the iliac nodes situated upon the promontory.

The Prostate Gland.—The lymphatics of the prostate have their origin in net-works surrounding the various acini of the gland. From these net-works stems pass to the surface, where they form a second net-work, and from this the efferent stems pass symmetrically on either side of the median line to somewhat diverse terminations. One or two of the efferents on either side ascend in a tortuous course upon the posterior surface of the bladder, and then bend laterally over the obliterated hypogastric arteries to terminate in one of the middle series of the iliac nodes which accompany the external iliac vessels. Another stem passes backward along the prostatic vessels to terminate in one of the hypogastric nodes ; others pass at first backward on either side of the rectum, and then ascend upon the anterior surface of the sacrum to terminate in the lateral sacral nodes or in the iliac nodes situated on the promontory of the sacrum ; and from the anterior surface of the gland a stem

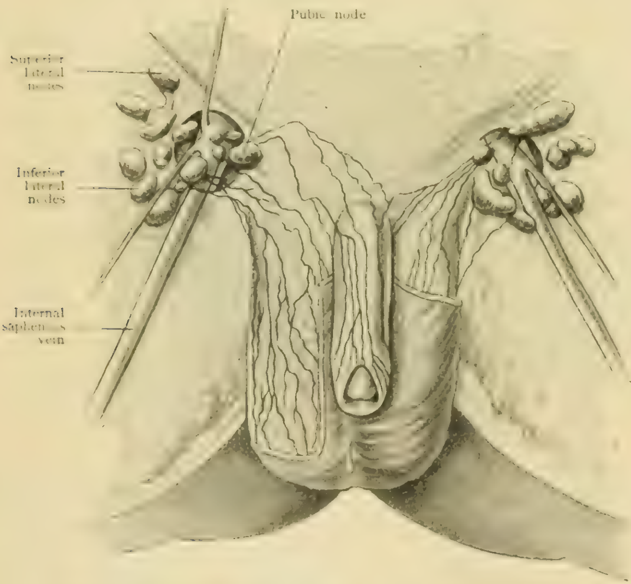
* Archiv f. Anatom. u. Physiol., 1897.

passes downward on either side of the membranous portion of the urethra, and, accompanying the urethral lymphatics along the course of the internal pudic vessels, terminates in one of the hypogastric nodes situated upon these vessels.

The Urethra.—The mucous membrane of the male urethra is furnished throughout its entire extent with a lymphatic net-work, which is especially rich in the region of the glans and diminishes in complexity in the membranous and prostatic portions of the duct. In the last region it communicates with the net-work in the muscular coat of the neck of the bladder. The efferents from the membranous portion of the duct associate themselves with some of the prostatic efferents and pass to a hypogastric node situated on the course of the internal pudic vessels, and those from the penial portion accompany the vessels which arise from the glans and will be described in the account of the lymphatics of the penis. The net-work of the female urethra corresponds with those of the membranous and prostatic portions of the male duct.

The External Reproductive Organs in the Male.—The lymphatics of the **scrotum** form an exceedingly rich net-work, especially well developed in the vicinity of the raphe and thence extending laterally over the entire surface. From six to eight stems arise from this net-work, and the uppermost accompany and eventually anastomose with the superficial efferents from the penis and terminate in the inner inguinal nodes. The remaining stems pass upward and outward to terminate in the inner superficial subinguinal nodes.

Fig. 827.



Superficial lymphatic vessels of penis and scrotum and inguinal nodes. (*Bruhns.**)

The lymphatics of the **penis** are divisible into a superficial and a deep set which correspond respectively to the superficial and deep blood-vessels of the organ. The *superficial set* forms a net-work in the integument of the penis which radiates in all directions from the frenulum, some stems passing forward and upward into the prepuce and some especially strong stems passing dorsally in the furrow behind the corona of the glans. As they approach the dorsal mid-line these latter give off one or two longitudinally directed efferents, or else they unite to form a single stem which runs along the dorsal mid-line. Other stems arising from the more proximal portions of the net-work curve upward from below over the lateral surfaces of the penis, and either unite with the dorsal stems or form independent lateral stems parallel with the dorsal ones. Numerous anastomoses occur between all the longitudinal stems throughout their courses, and, as they approach the symphysis, they bend laterally, some indeed dividing to send branches to either side, and, after the upper stems from the scrotum have united with them, they terminate in the inner inguinal nodes.

The *deep set* forms a net-work especially well developed in the glans, in which a superficial and a deep layer may be distinguished. Both these layers communicate at the meatus with the urethral net-work, and from the deeper layer a special plexus

* Archiv f. Anat. u. Physiol., 1900.

is developed on either side of the frenulum (*Panizza's plexus*), from which stems ascend in the groove back of the corona glandis. Into these stems the superficial layer of the net-work opens, and they also receive communications from the superficial vessels of the penis. From them one or two stems arise which pass proximally in company with the dorsal vein of the penis toward the suspensory ligament. Here they usually divide to form a more or less distinct plexus, lying immediately over the symphysis pubis and provided with some small lymphatic nodes, and from it two or three stems pass off laterally on either side. These pass across the surface of the pectineus muscle and beneath the spermatic cord, and some then pass either to the inner inguinal or deep subinguinal glands, while others extend along Poupart's ligament to the external abdominal ring and, traversing the inguinal canal, terminate in one of the lower iliac nodes.

It is to be noted that owing to the anastomoses and bifurcations of both the superficial and deep longitudinal stems it is possible that a unilateral infection may cause enlargment of the nodes of both sides.

The External Reproductive Organs in the Female.—The lymphatics of the external female genitalia have essentially the same distribution as those of the corresponding organs in the male. In both the **labia majora** and **minora** rich subcutaneous net-works occur, from which numerous stems arise and pass to the innermost inguinal and occasionally the inner superficial subinguinal nodes. The stems from the upper parts of the labia ascend at first directly upward toward the mons veneris and then bend suddenly outward to reach their terminal nodes ; those from the lower parts pass either directly upward and outward or else at first directly upward parallel to the outer edges of the labia and then bend suddenly outward. Some of the stems coming from one or other of the labia may pass to the nodes of the opposite side, and, furthermore, communications exist through the anterior and posterior commissures between the net-works of the opposite labia, so that a unilateral infection may produce enlargement of the inguinal nodes on both sides.

The lymphatics of the **clitoris** present essentially the same arrangement as the deep lymphatics of the penis. They form a rich net-work in the glans and from this longitudinal stems arise and pass toward the symphysis pubis, in front of which they form a plexus which usually contains some small nodes. From the plexus stems arise which pass laterally, and terminate either in one of the deep subinguinal nodes or else in the lower iliac nodes, which they reach by traversing the inguinal canal.

The Perineum and Circumanal Regions.—The deeper lymphatics of these regions have been considered in connection with the organs to which they belong and there remain for consideration only the subcutaneous vessels. These in the perineal region form an abundant net-work from which stems pass forward, for the most part in the furrow between the perineum and the inner surface of the thigh, and, associating themselves with the stems from the scrotum or labia majora, terminate in the inner inguinal or superficial subinguinal nodes.

The subcutaneous lymphatics which surround the **anal opening** also form a rich net-work, which communicates extensively with that of the anal mucosa (page 979). From it some two or three stems pass forward along the inner side of the thigh to terminate with the perineal and scrotal (labial) stems in the inner inguinal nodes.

The Internal Reproductive Organs in the Male.—The **testis** possesses an abundant supply of lymphatics, which may be divided into a deep and a superficial set. The former takes its origin in a rich net-work which surrounds the seminal ducts, and the stems which compose it pass toward the hilum in the septa, and, issuing, associate themselves with the stems arising from the superficial net-work. This is double, one layer of it lying beneath the tunica albuginea and the other between that investment and the visceral layer of the tunica vaginalis. Both layers are abundantly connected by vessels which traverse the tunica albuginea, and the deeper layer also receives numerous communicating stems from the deep lymphatics and from the lymphatics of the epididymis. Collecting stems from both layers converge toward the hilum, where they become associated with the stems from the deep net-work, from six to eight or rarely more trunks which ascend along the spermatic cord to the internal abdominal ring. They then follow the course of the spermatic veins upward, and terminate in from two to four of the lateral lumbar nodes (Fig. 816). The nodes to which the vessels from

the left testis pass lie immediately beneath the level of the renal veins, while those in which the stems from the right testis terminate are lower, being situated about midway between the level of the renal vein and the junction of the common iliac veins.

The lymphatics of the **vas deferens** are probably arranged in two net-works, one belonging to the mucosa and the other to the muscular coat, although so far only the latter net-work has been demonstrated. At the testicular end of the duct the net-work communicates with that of the epididymis, and the stems which arise from it accompany those of the testis to the lateral lumbar nodes. At the vesical end the net-work communicates with that of the seminal vesicles and its efferents pass to one of the hypogastric nodes.

The lymphatics of the **seminal vesicles** are much more readily demonstrable than those of the vasa deferentia. They arise from two net-works, one of which is situated in the mucosa and the other in the muscularis. Stems from the latter form a third net-work over the surfaces of the vesicles and from this efferents, two or three in number, pass to some of the hypogastric nodes.

The Internal Reproductive Organs in the Female.—The lymphatics of the **ovary** are very abundant throughout the substance of the organ, a fine net-work

FIG. 828.

Lymphatics of internal reproductive organs of female. (*Poirier.**)

surrounding each of the Graafian follicles. The stems which arise from these net-works converge toward the hilus, where they form a rich plexus and from this from six to eight efferents arise and follow the ovarian blood-vessels to terminate in the lateral lumbar nodes (Fig. 828).

Owing to thinness of the walls it is difficult to distinguish a definitely layered arrangement of the lymphatic net-work of the **Fallopian tubes.** It is, however, rich, and communicates with that of the fundus of the uterus. It gives rise to two or three efferents which accompany the ovarian efferents to the lateral lumbar nodes.

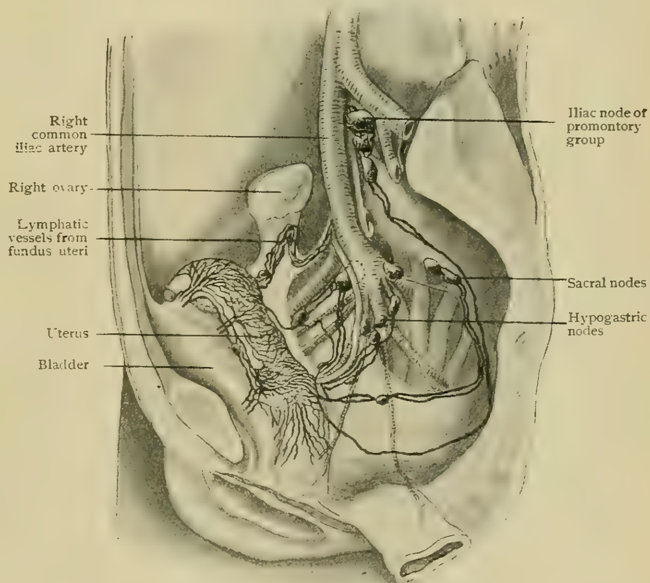
* Progrès Medical, 1890.

In the **uterus** (Figs. 828, 829) the conditions are much more favorable for determining the existence of separate net-works in the mucosa and muscularis than in the Fallopian tubes, but, nevertheless, much difference of opinion exists as to the occurrence of a mucosa net-work. That of the muscularis can be injected without difficulty, but no conclusive injections have yet been made of the mucosa, and while some authors (Bruhns, Sappey, Poirier) are inclined to admit the existence of a net-work in it, others (Leopold) deny it. However that may be, a well-developed net-work occurs in the muscular coat, in the deeper portions of which it becomes especially rich, and, furthermore, it is more abundant in the cervix than in the body or fundus. From it stems pass to the surface of the organ to form a subserous net-work, from which a number of efferents arise.

These may be divided into three principal groups according to their terminations. (1) The efferents from the fundus, usually two in number, pass outward on either side in the upper portion of the broad ligament, and, associating themselves with the efferents from the ovary, terminate in the lateral lumbar nodes. (2) Small stems pass from the fundus along the round ligament of the uterus to terminate in the inguinal nodes. (3) The efferents from the body and cervix pass laterally to terminate in the median iliac nodes situated in the angle between the external and internal iliac arteries. In the course of these last vessels, at the point where they cross the ureter, a small *utero-vaginal node* is occasionally placed.

Other efferents have been described as passing from the cervix to a hypogastric node situated at the origin of the uterine or vaginal artery, and two or three stems have been found arising from the posterior surface of the cervix and passing backward on either side of the rectum to the anterior surface of the sacrum, up which they pass to terminate in the iliac nodes situated upon the sacral promontory (Fig. 829).

Fig. 829.



Lymphatics of uterus. (*Cunéo and Marcille.**)

In the **vagina** there is no question as to the existence of definite net-works in both the mucosa and muscularis. That of the mucosa (Fig. 830) is exceptionally fine and communicates abundantly with the coarser net-work of the muscularis, as well as with the net-work of the vaginal portion of the cervix above and with that of the labia minora below. From the muscularis net-work stems pass to the surface of the organ to form a third net-work, from which the main efferent stems arise, and these may be arranged in three groups according to their destinations: (1) those which arise from the *upper portion* of the vagina join the stems which pass from the cervix of the uterus (Fig. 830) and terminate with these in the median iliac nodes situated in the angle formed by the external and internal iliac arteries; (2) those arising from the *middle portion* accompany the vaginal vessels, passing obliquely upward, outward, and backward, to terminate in one or two hypogastric nodes situated at the origin of the uterine arteries; and (3) those from the *lower portion* associate themselves with those from the labia minora and terminate with these

* Bull. et Mèm Société anatom., 1902.

in the inner inguinal nodes. Certain of the stems from the middle portion also pass to the same middle iliac nodes which receive the efferents from the upper portion, and stems have been observed (Bruhns) passing from the posterior surface of the vagina to the lateral lumbar nodes and even to the iliac nodes situated on the promontory of the sacrum, while others have been traced to the anorectal nodes (page 976). Finally, it may be noted that the superficial net-work of the anterior surface of the vagina communicates with that of the posterior surface of the bladder.

FIG. 830.

Lymphatic net-work of vaginal mucous membrane. (*Poirier.**)

Practical Considerations.—*The Lymph-Nodes of the Abdomen and Pelvis.*—The *superficial* lymphatics of the wall of the abdomen convey infection, if the primary focus is above the level of the umbilicus, to the axillary nodes; if it is below that level, to the inguinal nodes. Hence, in cases of furuncle or carbuncle, or of chancre, or of epithelioma, the site of the lesion would determine the region in which adenopathy should be sought.

The *cœliac group of nodes* may be involved in diseases of the greater portion of the digestive tract, or of the stomach, spleen, or part of the liver; or their enlargement may follow that of the lumbar or of the mesenteric nodes. The nodes in and about the portal fissure, or between the layers of the gastro-hepatic omentum may so enlarge in cases of carcinoma of the stomach or of the liver as to compress the portal vein (causing ascites) or the common bile duct (causing jaundice).

The lymphatic relations of the stomach, liver, spleen, and pancreas have been sufficiently considered from the practical stand-point in connection with these viscera.

The *mesenteric nodes* are frequently and gravely involved in various intestinal diseases. They are often infected and enlarged during typhoid fever. They are especially implicated in peritoneal or intestinal tuberculosis. The lymphoid nodules in the neighborhood of Peyer's patches are surrounded by lymphatic plexuses and are a common site of tuberculous ulceration. The bacilli tuberculosis are carried directly thence to the mesenteric glands (tabes mesenterica), and sometimes by way of the lymphatic vessels and thoracic duct, may reach the general circulation in large numbers (generalized tuberculosis, acute miliary tuberculosis). In some cases of tuberculous peritonitis associated with mesenteric gland disease, the mesentery undergoes marked and extreme contraction, so that the altered coils of intestine are held closely to the spine, and their lumen may be greatly narrowed (peritonitis deformans) (Taylor).

Mesenteric cysts (serous or chylous cysts) are usually of lymphatic origin, and may be due to lymphatic obstruction or to a degeneration and dilatation of the mesenteric nodes analogous to the varicosity of inguinal nodes in filarial disease. The clinical signs of such cysts are: 1, a prominent, fluctuating, usually spherical swelling near the umbilicus; 2, marked mobility of the tumor—especially in a transverse direction and around the central axis; 3, the presence of a zone of resonance around the cyst and a belt of resonance across it (Moynihan). The symptoms may be

* Progrès medical, 1890.

either (*a*) chronic, of the nature of colicky pain due to interference with the intestine and to gastro-intestinal disturbance, the presence of a tumor distinguishing the case from one of simple gastro-enteritis ; or (*b*) those of acute intestinal obstruction (Rolleston).

The *lumbar nodes* may be enlarged from septic or malignant disease of the lower extremities, the testes, the fundus of the uterus, the ovary, the kidneys and adrenals, the sigmoid or rectum. The wide area thus drained by them exposes them frequently to transmitted infection or disease. Their condition in the presence of carcinoma affecting any of these regions or viscera has an important practical bearing upon the question of operative interference, as, practically without exception, if they are involved only palliation can be hoped for. With an empty intestinal tract and a thoroughly relaxed abdomen, even moderate enlargement of these nodes may, in thin persons, be detected by palpation. In persons with very muscular or very fat abdominal walls, they cannot be felt until they have formed a considerable mass. Their great enlargement—especially in carcinoma—often results in swelling and œdema of the lower extremities on account of the obstruction to the current in the inferior cava produced by the pressure of the dense indurated glands which may quite encircle both that vessel and the aorta and may even interfere with the circulation in the latter.

The lumbar nodes often enlarge consecutively to enlargement of the *pelvic nodes* (obturator, gluteal, sciatic, internal pudic, external and internal iliacs), some of which are also palpable—in thin persons—when the subject of carcinomatous infiltration. The external iliac nodes, for example, lying along the anterior and inner aspect of the external iliac vessels, may, when cancerous, be recognizable in this way, and may be found by their tenderness—though less distinctly felt—in some septic cases. As they receive the lymphatic vessels from the nodes of the groin, and the vessels accompanying the deep circumflex iliac arteries, their enlargement may follow that of the inguinal nodes, or may result from septic or syphilitic or cancerous foci in the supra-inguinal portion of the abdominal wall. In cancer of the testis the iliac and lumbar nodes are in the closest relation to the ascending current of lymph, the inguinal nodes, as a rule, being involved later, after the skin of the scrotum has become infiltrated or ulcerated. In advanced cases of carcinoma of the rectum or uterus, the obturator, epigastric and external iliac groups become considerably affected. Œdema of the legs often results because (*a*) the enlarged nodes press directly upon the external iliac vessels ; and (*b*) the lymphatics pass both over and under these vessels to communicate with the obturator node and thus compress the vein in a ring-like carcinomatous mass (Leaf). The pain felt in these cases is due to the pressure of the affected glands upon the nerve-trunks arising from the lumbo-sacral plexus. Similar pains may be felt when any of the pelvic glands are involved as there is a similarly close relation between the obturator node and the obturator nerve ; the gluteal, sciatic, and internal pudic nodes and the first and second sacral and great sciatic nerves ; and the external iliac nodes and the anterior crural nerve. The obturator group of nodes lying between the external iliac vein and the obturator nerve assume surgical importance because sometimes the lowest node of this group is found projecting through the crural canal. The relation of this node to Gimbernat's ligament shows that when enlarged it would appear as a swelling occupying a position similar to that of a femoral hernia (Leaf). Cases are on record (White) in which an inflammation of this node has simulated a strangulated femoral hernia.

THE LYMPHATICS OF THE LOWER EXTREMITY.

The Lymphatic Nodes.

The Inguinal Nodes.—The principal group of nodes of the lower extremity is situated in the inguinal region over Scarpa's triangle, where they form a considerable mass, placed for the most part between the layers of the fascia lata, and consist of from twelve to twenty nodes united by connecting branches to form a plexus, the **plexus inguinalis.** Though in reality forming a single group, they have been divided for purposes of description into a number of subordinate groups which must be recognized to have merely a conventional value. The first of these divisions is a

separation of the nodes which lie respectively above and below a horizontal line drawn through the point at which the long saphenous vein pierces the cribriform fascia, and to those lying above this line the term **inguinal nodes** (lymphoglandulae inguinales) is applied, while those below it are termed the **subinguinal nodes** (lymphoglandulae subinguinales). This latter subgroup is again divided into a *superficial* (lymphoglandulae subinguinales superficiales) and a *deep* (lymphoglandulae subinguinales profundae) set, according as they are situated on or beneath the fascia lata. Finally, by means of a vertical line passing through the orifice in the cribriform fascia through which the long saphenous vein passes, the inguinal and superficial subinguinal groups are each subdivided into an *inner* and an *outer* set, a small central group of nodes, surrounding the saphenous orifice, being also sometimes recognizable. It may, however, again be emphasized that these subdivisions are purely conventional and cannot always be clearly distinguished, nor do they represent, except in a very general way, the terminations of definite drainage areas. Indeed, the numerous connections which exist between the nodes of the various subgroups cause their distinction to be of comparatively little importance from the surgical stand-point.

FIG. 831.

Superficial inguinal lymph-nodes; horizontal line subdivides nodes into upper and lower groups; vertical line into median and lateral groups.

The **inguinal nodes** are arranged in a more or less distinct chain over the base of Scarpa's triangle, immediately below Poupart's ligament. They receive as *afferents* the superficial lymphatics of the abdominal walls and the gluteal region, the superficial vessels of the scrotum and penis in the male and of the labia majora and minora in the female, as well as those from the perineum and the circumanal region. Their *efferents* perforate the cribriform fascia, enter the abdomen by the femoral ring, and terminate in the lower iliac nodes.

The **superficial subinguinal nodes** receive some *afferents* from the gluteal regions and also some from the perineum and circumanal regions, but the principal set is formed by the superficial vessels of the leg. Their efferents have essentially the same course as those of the inguinal nodes, piercing the cribriform fascia to accompany the femoral vessels to the abdomen, where they terminate in the lower iliac nodes. In their course through the femoral sheath some of them lie on the anterior surface of the vessels, but the majority lie on their inner side in the crural canal and some of them terminate in the deep subinguinal nodes.

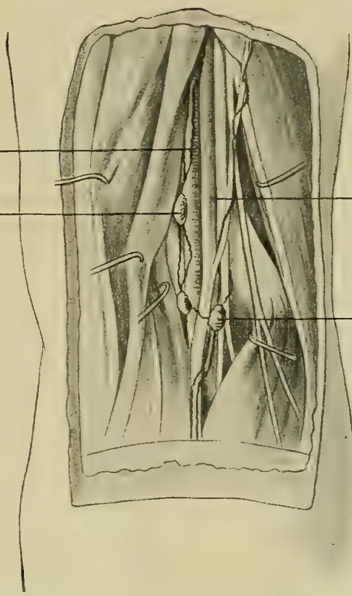
The **deep subinguinal nodes** vary in number from one to three. They are placed along the course of the femoral vein, one occurring immediately beneath the point of junction of the long saphenous vein with the femoral, a second a little higher up in the crural canal, and the third, termed by French authors the *node of Cloquet* and by the Germans the *node of Rosenmüller*, is situated at the entrance into the crural canal from the abdomen. Their principal *afferents* are the deep lymphatics of the thigh which accompany the femoral vessels and their branches, but in addition they receive stems from the superficial subinguinal nodes and the deep vessels of the penis and clitoris. Their *efferents* pass, like those of the superficial nodes, to the lower iliac nodes.

The **popliteal nodes** (lymphoglandulae popliteae) are some four or more in number and are embedded in the adipose tissue of the popliteal space (Fig. 832). One or two occur in the neighborhood of the short saphenous vein immediately after it has entered the popliteal space, while the rest are situated more deeply upon the popliteal vessels. The more superficial nodes receive as *afferents* the superficial lymphatics of the leg which accompany the short saphenous vein, while the deeper

ones receive the vessels which accompany the branches of the popliteal vessels and also those accompanying the anterior and posterior tibial vessels. Their *efferents* for the most part accompany the femoral vessels to terminate in the deep subinguinal nodes.

The **anterior tibial node** (**lymphoglandula tibialis anterior**) is a small and probably inconstant node situated in the upper part of the course of the lymphatic vessels which accompany the anterior tibial artery. Its *efferents* pass upward along with the anterior tibial and popliteal blood-vessels to terminate in the deeper popliteal nodes.

FIG. 832.



Popliteal lymph-nodes. (*Poirier and Cunéo.**)

THE LYMPHATIC VESSELS.

The lymphatic vessels of the lower extremity may be divided into two groups, one of which consists of the subcutaneous net-work and its efferent stems and the other of those vessels which accompany the principal blood-vessels.

The **superficial lymphatics** take their origin from a net-work distributed throughout all portions of the subcutaneous tissue of the extremity, but increasing in richness and complexity toward the distal part of the limb, until in the foot, and especially in the plantar region, it forms a very close and abundant net-work. This plantar net-work extends not only throughout the entire plantar region, but curves dorsally upon both the outer and inner borders of the foot, and also over the posterior surface of the heel, and from these lateral and posterior portions of the net-work as well as from the subcutaneous net-work of the digits numerous collecting stems arise. These anastomose abundantly, and those from the digits, the whole of the inner border of the foot and the distal half of its outer border form an open plexus upon the dorsum of the foot. The stems, several in number, which arise from this plexus pass upward along the inner surface of the leg (Fig. 833), following in general the course of the long saphenous vein and receiving as they go communications from the superficial net-works of the regions they traverse. In the neighborhood of the knee stems arising from the net-work over the anterior tibial region become associated with them, and above the knee branches which drain the net-work of the outer, inner, and posterior surfaces of the thigh also curve upward and inward or forward, as the case may be, to accompany them. The numerous stems so formed are all situated superficially to the fascia lata, and terminate above in the superficial subinguinal nodes, the more anterior stems passing to the outer and the more posterior to the inner members of the group.

The stems which arise from the calcaneal portion of the plantar net-work and from that portion of it which curves upward over the posterior half of the outer border of the foot, pass upward upon the posterior surface of the crus in company with the short saphenous vein. They receive communications from the superficial net-work of the calf and, as they approach the bend of the knee, they perforate the crural fascia and terminate in the more superficial popliteal nodes.

Finally, from the net-work over the gluteal region a number of collecting stems arise, the majority of which curve forward and converge to terminate in the outer inguinal nodes, some from the more posterior portions of the net-work, however,

* Poirier et Charpy : Traité d'anatomie humaine, Tome ii., 1902.

passing forward along with the stems from the circumanal region to the inner inguinal or superficial subinguinal nodes.

The **deep lymphatics** of the lower extremity take their origin mainly in the muscles and form stems which accompany the blood-vessels. From the net-work of the plantar muscles one or two stems take origin which follow the course of the plantar arch, ascending to the dorsum of the foot between the first and second metatarsal bones. They then follow the course of the dorsal pedal vessels, receiving the stems which accompany their branches, and then accompany the anterior tibial vessels up the leg. After traversing the anterior tibial nodes they pass with the vessels through the foramen in the interosseous membrane, and, continuing their upward course through the popliteal space, terminate in the deeper popliteal nodes.

Fig. 833.

Superficial lymphatic vessels of lower limb; semidiagrammatic. (Based on figures of *Sappey*.)

Other branches arising in the plantar musculature follow the plantar vessels backward, and, ascending behind the internal malleolus, accompany the posterior tibial vessels. Toward the upper part of the crus they receive the stems which accompany the peroneal vessels and their branches, and terminate, like the anterior stems, in the deeper popliteal nodes.

From these nodes four large stems issue, and, passing through the hiatus tendineus of the adductor magnus, continue their course up the thigh in company with the femoral vessels. They receive the stems which accompany the various branches of the femoral vessels and terminate above in the deep subinguinal nodes. In addition to these deep femoral lymphatics others occur in the thigh in company with the obturator and sciatic vessels, and the muscles of the gluteal region are drained by stems which accompany the gluteal vessels. All these stems terminate in nodes belonging to the hypogastric group, those accompanying the sciatic vessels traversing some small and inconstant nodes situated beneath the pyriformis muscle, while some ten or twelve similar nodes occur along the course of the gluteal stems.

Practical Considerations.—*The Nodes of the Lower Extremity.*—The majority of the lymphatics of the sole of the foot unite with those of the inner side of the dorsum and run with the long saphenous vein to enter the inguinal nodes. A smaller number run up the fibular side of the leg, but most of these cross over the leg or at the ham to join the inner lymphatic vessels. A still smaller number run with the short saphenous vein and empty into the popliteal nodes. The far more frequent occurrence of glandular swellings and abscess in the groin than in the ham is thus easily understood.

The *popliteal nodes* (*intercondylar*, lying on either side of the popliteal artery between the two heads of the gastrocnemius, and *supracondylar*, lying deeper and against the back of the femur) are extremely difficult to feel unless they are enlarged, and even then the only one which can be detected is that which lies over the internal popliteal nerve. This node, probably from the constant movement of the knee-joint, is very apt to suppurate as a result of superficial sores about the heel. The intercondylar nodes cannot be felt; in the first place, because of their deep position, and secondly, because when pressed they become still further forced down between the condyles. The supracondylar nodes lie altogether too deep to be felt by the fingers (Leaf). A small node beneath the fascia close to the point of entry of the short saphenous receives some of the lymphatics that accompany that vein.

Popliteal abscess will follow pyogenic infection of the popliteal nodes. The pressure effects due to the density and rigidity of the popliteal fascia and the consequent necessity for early and free incision and drainage have already been described (pages 646). Enlargement of the popliteal nodes has been mistaken for enlarged bursæ—though the nodes are deeper and nearer the median line—for popliteal aneurism, and for neoplasms.

The *inguinal nodes* are numerous and, on account of their frequent involvement in diseases of the lower extremity and of the genitals, are important. The arrangement into a *superficial* and *deep set*, and the division of the former into two groups, the *horizontal*, parallel with and close to Poupart's ligament, and the *vertical*, parallel with and close to the long saphenous vein, is of convenience. The deep set is found to the inner side of the femoral vein and may be said to include one group which is embedded in the fatty layer at the saphenous opening and bears the same relation to the fascia lata that the central group of axillary glands bears to the axillary fascia (Leaf) (page 581). The inguinal nodes receive lymph through the superficial lymphatics as follows: Lower limb—vertical set of superficial nodes; lower half of abdomen—middle nodes of horizontal set; outer surface of buttock—external nodes of horizontal set; inner surface of buttock—internal nodes of horizontal set, (a few of these vessels go to the vertical nodes; external genitals—horizontal nodes, a few going to the vertical set; perineum-vertical set. The deep lymphatics of the lower limb enter the deep set of nodes (Treves). The deep lymphatics of the penis and those that are found with the obturator, gluteal, and sciatic vessels enter the pelvic nodes. The inguinal nodes communicate with the external and common iliac nodes, the pelvic lymphatics with the internal iliac nodes, and both the iliac groups with the lumbar nodes. The deep node lying in the crural canal and upon the septum crurale is variously described as one of the obturator (pelvic) group (Leaf) and as one of the deep set of inguinal nodes (Treves). It should be remembered that when it is inflamed it may not only simulate strangulated hernia, but, on account of the density of the structures by which it is surrounded and their participation in the movements of the thigh, may give rise to pain suggesting coxalgia.

The relations of branches of the anterior crural nerve to the inguinal nodes may, in cases of inflammation or enlargement, give rise to pain or spasm in the region supplied by that nerve. Filariasis (elephantiasis arabum) of the femoral lymphatics, which are obstructed by the worms, gives rise to very great swelling of the lower extremity (Cochin leg, Barbadoes leg).

In addition to what has been stated above the practical application of a knowledge of the lymphatics of the lower extremity embraces the following considerations:

(*a*) The lymphatic vessels may be inflamed without involvement of the veins, when the course of some of the main vessels can be distinctly traced under the skin. When chronically inflamed, and obstruction exists at the nearest lymphatic gland, the vessels may become thickened, dilated, and tortuous. The lymphatic vessels of the sheath of the penis are, perhaps, more frequently involved in diseased action than those of any other portion of the skin surface. Inflamed lymphatic vessels often co-exist with a chancre. In cases of neglected chancre, associated with an indurated condition of the lymphatic nodes of the groin, they may even form bulla-like swellings which sometimes rupture and permit the lymph to escape externally. Rarely dilatation of the lymphatic vessels occurs without apparent cause.

(*b*) The lymphatic vessels may, from causes imperfectly understood, become filled with chylous fluid. In one (Petters), remarkable dilatation of the lymphatics existed in the right groin and in the abdomen, in a patient the subject of valvular heart disease. The glands were converted into cyst-like cavities filled with a yellow fluid. Rosary-like dilatations, similar to those seen at the elbow, occur infrequently below the groin.

The inguinal lymphatic glands are the common seat of diseased action dependent upon the transmission of the virus of syphilis, or of any other irritant whose point of entrance is through the external genitals. In the nonsyphilitic infections they frequently suppurate or excite suppurative cellulitis in the parts about them. Acute inflammatory engorgement of one of them has been known to induce fatal peritonitis by direct continuity through the lymphatic vessels of the abdominal wall (Allen).

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